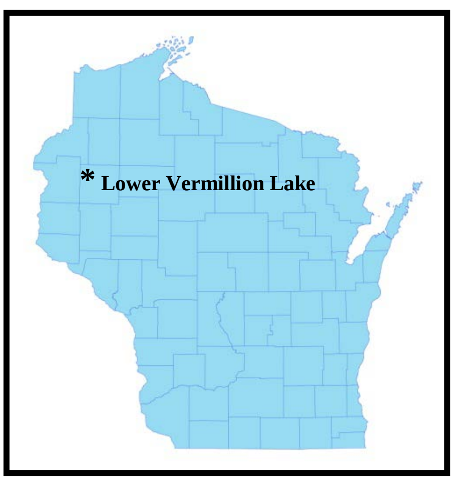
Early-season Curly-leaf pondweed (*Potamogeton crispus*) and Eurasian Water-milfoil (*Myriophyllum spicatum*) Point-intercept and Bed Mapping Surveys, and Warm-water Point-intercept Macrophyte Survey Lower Vermillion Lake - WBIC: 2098200 Barron County, Wisconsin

EWM raked out by landing 7/20/21

Lower Vermillion Lake Aerial Photo (2015)

Project Initiated by:

Vermillion Lakes Association, Wisconsin Department of Natural Resources and Lake Education and Planning Services, LLC (WDNR Grant ACEI25221)



Maximum Northern wild rice density in the southeast outlet bay 7/20/21

Surveys Conducted by and Report Prepared by:

Endangered Resource Services, LLC
Matthew S. Berg, Research Biologist
St. Croix Falls, Wisconsin
May 29 and July 20, 2021

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ABSTRACT

Lower Vermillion Lake (WBIC 2098200) is a 215-acre stratified drainage lake located in northwestern Barron County, WI. Following the discovery of Eurasian water-milfoil (*Myriophyllum spicatum*) (EWM) in 2008, the Vermillion Lakes Association (VLA), under the direction of Dave Blumer (Lake Education and Planning Services, LLC), developed Aquatic Plant Management Plans using data from the lake's 2009 and 2016 point-intercept surveys. As a prerequisite to updating their plan in 2022 and to compare how the lake's vegetation may have changed since the last point-intercept surveys, the VLA and the Wisconsin Department of Natural Resources authorized early-season exotic species point-intercept and Curly-leaf pondweed (*Potamogeton crispus*) bed mapping surveys on May 29th, and a full point-intercept survey for all aquatic macrophytes on July 20, 2021. The 2021 spring survey found CLP at 33 points (4.9% total lake coverage and 16.4% of the spring littoral zone) with a mean rake fullness of 1.33. This was a non-significant increase (p=0.16) in distribution, and a non-significant decline in total rake fullness (p=0.32) when compared to the 2016 survey (24 points with a mean rake of 1.42/3.6% lake coverage and 11.3% of the spring littoral zone). Despite this increase in coverage compared to 2016, the 2021 total was still down from 56 points with a mean rake of 1.71 in 2009 (8.3% of the lake/26.7% of the spring littoral zone). The 2021 survey suggested 1.3% of the lake/4.3% of the littoral zone had a potentially significant infestation (nine total points with a rake fullness of 2 or 3). Although this was up from 0.9% (seven points) in 2016, it was still well below 2009 when 29 points (4.3% coverage) had a significant infestation. From 2016 to 2021, the only significant change in CLP was an increase in visual sightings **(p<0.05)**. However, when comparing the mean rake fullness from the original spring 2009 survey to 2021, we noted an overall moderately significant decline **(p=0.006)** in density. EWM was present at two points each with a rake of 1 (0.3% of the lake/1.0% of the littoral zone). This was up from 2009 and 2016 when we didn't find EWM in the rake at any point during the spring point-intercept survey. In 2021, we mapped eight CLP beds that totaled 10.85 acres and covered 5.0% of the lake's surface area. This represented a 7.19-acre increase (+196%) from the nine CLP beds on 3.66 acres (1.7% coverage) mapped in 2016. It was also sharply higher than the single CLP bed on 1.10 acres (0.6% coverage) we found during our original 2009 survey. During the July 2021 full point-intercept survey, we found macrophytes growing at 189 sites (28.2% of the lake bottom and 76.5% of the 14.0ft littoral zone). This was a non-significant decline (p=0.17) from 2016 when plants were present at 212 points (31.6% of the bottom/90.2% of the 13.5ft littoral zone). However, it represented a significant decline **(p=0.01)** from the 2009 survey when we found plants growing at 232 points (34.6% of the bottom/88.9% of the then 16.0ft littoral zone). Overall diversity was very high with a Simpson Diversity Index value of 0.89 – down from 0.91in 2016 and 0.93 in 2009. Species richness was moderate with 44 species found growing in and immediately adjacent to the water - nearly unchanged from 43 total species found in in 2016/42 in 2009. Although total richness increased, mean native species richness at sites with native vegetation experienced a highly significant decline **(p<0.001)** from 3.52/site in 2009 to 3.01/site in 2016 and a further highly significant decline to 2.34/site in 2021. Visual analysis of the maps showed most of these losses occurred in the east bay. Total rake fullness experienced a highly significant decline **(p<0.001)** from a moderately high 2.43 in 2009 to a low/moderate 1.85 in 2016 – potentially due to poor clarity. In 2021,

this trend reversed as we found a highly significant increase **(*p*<0.001)** to a moderate mean rake of 2.14. In July 2009, Coontail (*Ceratophyllum demersum*), Flat-stem pondweed (*Potamogeton zosteriformis*), Slender naiad (*Najas flexilis*), and Wild celery (*Vallisneria americana*) were the most common macrophyte species. Present at 49.14%, 47.84%, 29.74%, and 29.74% of survey points with vegetation, they accounted for 44.11% of the total relative frequency. The July 2016 survey identified Coontail, Flat-stem pondweed, Wild celery, and Fries' pondweed (*Potamogeton friesii*) as the most common macrophyte species. They were found at 51.42%, 41.51%, 33.02%, and 29.72% of sites with vegetation and accounted for 51.48% of the total relative frequency. Lakewide, from 2009-2016, 12 species saw significant changes in distributions: Northern water-milfoil (*Myriophyllum sibiricum*), Stiff pondweed (*Potamogeton strictifolius*), White-stem pondweed (*Potamogeton praelongus*), and Illinois pondweed (*Potamogeton illinoensis*) suffered highly significant declines **(*p*<0.001)**; Clasping-leaf pondweed (*Potamogeton richardsonii*) **(*p*=0.002)** and Water star-grass (*Heteranthera dubia*) **(*p*=0.002)** experienced moderately significant declines; and Muskgrass (*Chara* sp.) **(*p*=0.03)**, Curly-leaf pondweed, and Spiny-spored quillwort (*Isoetes echinospora*) **(*p*=0.04)** demonstrated significant declines. Conversely, filamentous algae experienced a highly significant increase **(*p*<0.001)**; and Fries' pondweed **(*p*=0.01)** and Forked duckweed (*Lemna trisulca*) **(*p*=0.01)** showed significant increases. The 2021 survey documented Coontail (44.44% of points with vegetation), Wild celery (40.74%), Slender naiad (32.80%), and Muskgrass (29.10%) as the most common species with a combined relative frequency of 62.90%. From 2016 to 2021, eight species underwent significant changes in distribution. Flat-stem pondweed, Fries' pondweed, Small pondweed (*Potamogeton pusillus*), and Forked duckweed suffered highly significant declines **(*p*<0.001)**; and Variable pondweed (*Potamogeton gramineus*) saw a significant decline **(*p*=0.03)**. Conversely filamentous algae saw a highly significant increase **(*p*<0.001)**; Curly-leaf pondweed underwent a moderately significant increase **(*p*=0.006)**; and Muskgrass had a significant increase **(*p*=0.04)**. Northern wild rice (*Zizania palustris*) was again limited to the southeast outlet bay where we documented a low to moderate-density stand. The 32 native index species found in the rake during the July 2021 survey (similar to 33 in 2016/31 in 2009) produced an above average mean Coefficient of Conservatism of 6.0 (similar to 6.2 in 2016/6.0 in 2009). The Floristic Quality Index of 33.9 (similar to 35.5 in 2016/33.4 in 2009) was also above the median FQI for this part of the state. Filamentous algae were present at 97 sites with a mean rake of 1.49. This was a further highly significant increase **(*p*<0.001)** in distribution from the 72 points (mean rake 1.39) in 2016, and the 40 points with a mean rake of 1.80 in 2009. The July 2021 survey found CLP was still present at nine points all with a rake of 1. This was a moderately significant increase **(*p*=0.006)** in distribution compared to 2016 when we found a single CLP plant at a single point, but it was similar to July 2009 when CLP was also present at nine points with a mean rake of 1.22. The July 2021 survey recorded EWM as a visual at a single point. Other than CLP and EWM, Reed canary grass (*Phalaris arundinacea*) was the only other exotic plant species found on the lake. These results suggest the lake's current management strategy of targeted small-scale herbicide treatments coupled with manual removal is holding EWM in check.

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INTRODUCTION:

Lower Vermillion Lake (WBIC 2098200) is a 215-acres stratified drainage lake in northwestern Barron County, Wisconsin in the Town of Cumberland (T35N R13W S15/16, 22). It reaches a maximum depth of 55 feet in the central basin and has an average depth of approximately 25ft (Busch et al 1967) (Figure 1). The lake is mesotrophic in nature, and, from 2000-2021, water clarity has been fair to good with summer Secchi readings ranging from 6-12ft and averaging 8.7ft (WDNR 2021). This clarity produced a littoral zone that reached approximately 14.0ft in 2021. Bottom substrates along the north, south, and southeastern shorelines are primarily rock and sand, while most of the east bay and main basin are organic or sandy muck.

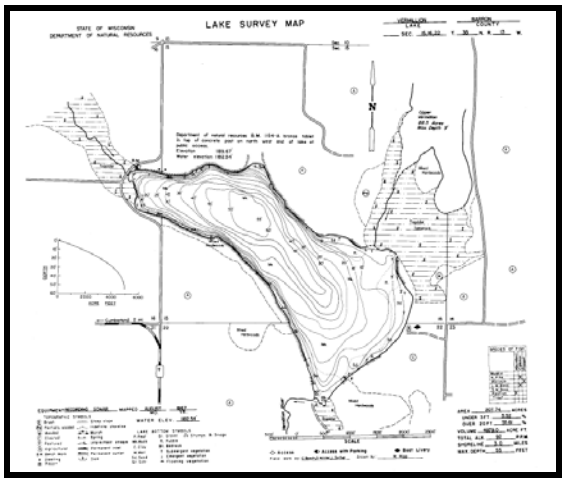


Figure 1: Lower Vermillion Lake Bathymetric Map

BACKGROUND AND STUDY RATIONALE:

Eurasian water-milfoil (*Myriophyllum spicatum*) (EWM), an exotic invasive plant species, was discovered in Lower Vermillion Lake in 2008. Since that time, the Vermillion Lakes Association (VLA) has engaged in active management using herbicides and manual removal as outlined in their Wisconsin Department of Natural Resources (WDNR) approved 2009 and 2017 Aquatic Plant Management Plans (APMP). In addition to EWM, the plans also addressed the lake's Curly-leaf pondweed (*Potamogeton crispus*) (CLP) infestation - another exotic invasive species that is especially common in areas of the lake with nutrient-rich sediments.

Per WDNR expectations (Pamela Toshner/Alex Smith, WDNR – pers. comm.), whole-lake plant surveys on actively managed lakes are normally repeated every five to seven years to remain current. In anticipation of updating their plan in 2022, the VLA, under the direction of Dave Blumer (Lake Education and Planning Services, LLC), requested three lakewide surveys on Lower Vermillion in 2021. On May 29th, we conducted early-season exotic species point-intercept and CLP bed mapping surveys. This was followed by a warm-water point-intercept survey of all macrophytes on July 20th. The surveys' objectives were to document current levels of CLP, EWM, and the lake's native macrophyte community; compare those results to the original 2009 surveys and the most recent 2016 surveys; and determine if any significant changes had occurred to the lake's vegetation over that time. This report is the summary analysis of these three field surveys.

METHODS:

Spring Exotic Species Point-intercept Survey:

Using a standard formula that takes into account the shoreline shape and distance, water clarity, depth, and total acreage, Michelle Nault (WDNR) generated the original 671-point sampling grid for Lower Vermillion Lake (Appendix I) in 2009. Using this same grid in 2016 and 2021, we completed a density survey where we sampled for Curly-leaf pondweed and Eurasian water-milfoil at each littoral point in the lake. We located each survey point using a handheld mapping GPS unit (Garmin 76CSx) and used a rake to sample an approximately 2.5ft section of the bottom. When found, CLP and EWM were assigned a rake fullness value of 1-3 as an estimation of abundance (Figure 2). We also noted visual sightings of these species when they were within six feet of the sample point.

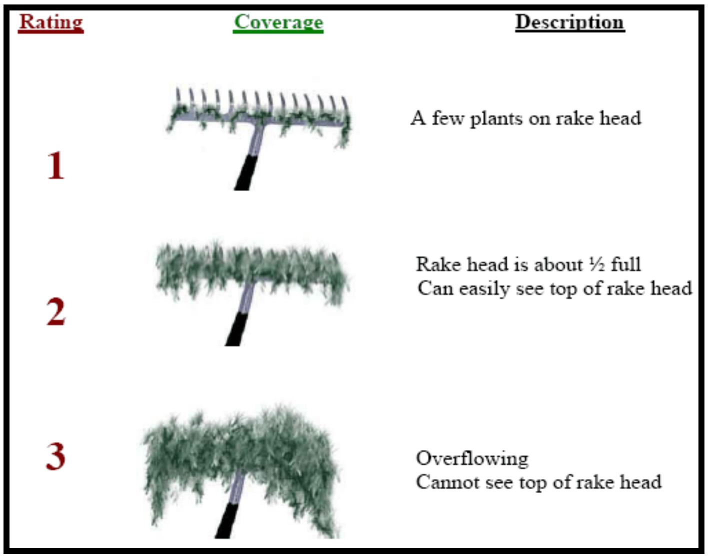


Figure 2: Rake Fullness Ratings (UWEX 2010)

Curly-leaf Pondweed and Eurasian Water-milfoil Bed Mapping Surveys:

During the spring Curly-leaf pondweed bed mapping survey, we searched the lake's visible littoral zone. By definition, a "bed" was determined to be any area where we visually estimated that CLP made up >50% of the area's plants, was generally continuous with clearly defined borders, and was canopied, or close enough to being canopied that it would likely interfere with boat traffic. After we located a bed, we motored around the perimeter of the area taking GPS coordinates at regular intervals. We also estimated the rake density range and mean rake fullness of the bed (Figure 2), the maximum depth of the bed, whether it was canopied, and the impact it was likely to have on navigation (**none** – easily avoidable with a natural channel around or narrow enough to motor through/**minor** – one prop clear to get through or access open water/**moderate** – several prop clears needed to navigate through/**severe** – multiple prop clears and difficult to impossible to row through). These data were then mapped using ArcMap 9.3.1, and we used the WDNR's Forestry Tools Extension to determine the acreage of each bed to the nearest hundredth of an acre (Table 1). We also recorded the GPS coordinates of all EWM plants found as they were generally few in number. These waypoints were shared with the SCUBA diver that was hired by the VLA in 2021 to do manual removal.

Warm-water Full Point-intercept Macrophyte Survey:

Prior to beginning the July point-intercept survey, we conducted a general boat survey of the lake to regain familiarity with the species present (Appendix II). All plants found were identified (Voss 1996, Boreman et al. 1997; Chadde 2002; Crow and Hellquist 2006; Skawinski 2019), and a datasheet was built from the species present.

During the survey, we again located each survey point with a GPS, recorded a depth reading with a metered pole rake, and took a rake sample. All plants on the rake, as well as any that were dislodged by the rake were identified and assigned a rake fullness value of 1-3 as an estimation of abundance (Figure 2). We also recorded visual sightings of all plants within six feet of the sample point not found in the rake. In addition to a rake rating for each species, a total rake fullness rating was also noted. Substrate (bottom) type was assigned at each site where the bottom was visible, or it could be reliably determined using the rake.

DATA ANALYSIS:

In an effort to visualize the changes on the lake since the first point-intercept survey in 2009, we included summary statistics and maps from each prior survey in the 2021 report and linked folders. We also updated pre-2010 data to the current standard aquatic plant management spreadsheet (Appendix II) (UWEX 2010). Using this same sheet for our 2021 survey, we entered all data collected in the field and calculated the following:

Total number of sites visited: This included the total number of points on the lake that were accessible to be surveyed by boat or kayak.

Total number of sites with vegetation: These included all sites where we found vegetation after doing a rake sample. For example, if 20% of all sample sites have vegetation, it suggests that 20% of the lake has plant coverage.

Total number of sites shallower than the maximum depth of plants: This is the number of sites that are in the littoral zone. Because not all sites that are within the littoral zone actually have vegetation, we use this value to estimate how prevalent vegetation is throughout the littoral zone. For example, if 60% of the sites shallower than the maximum depth of plants have vegetation, then we estimate that 60% of the littoral zone has plants.

Frequency of occurrence: The frequency of all plants (or individual species) is generally reported as a percentage of occurrences within the littoral zone. It can also be reported as a percentage of occurrences at sample points with vegetation.

> Frequency of occurrence example:
>
> Plant A is sampled at 70 out of 700 total littoral points = 70/700 = .10 = 10%
>
> This means that Plant A's frequency of occurrence = 10% when considering the entire littoral zone.
>
> Plant A is sampled at 70 out of 350 total points with vegetation = 70/350 = .20 = 20%
>
> This means that Plant A's frequency of occurrence = 20% when only considering the sites in the littoral zone that have vegetation.
>
> From these frequencies, we can estimate how common each species was at depths where plants were able to grow, and at points where plants actually were growing.
>
> Note the second value will be greater as not all the points (in this example, only ½) had plants growing at them.

Simpson's Diversity Index: A diversity index allows the entire plant community at one location to be compared to the entire plant community at another location. It also allows the plant community at a single location to be compared over time thus allowing a measure of community degradation or restoration at that site. With Simpson's Diversity Index, the index value represents the probability that two individual plants (randomly selected) will be different species. The index values range from 0 -1 where 0 indicates that all the plants sampled are the same species to 1 where none of the plants sampled are the same species. The greater the index value, the higher the diversity in a given location. Although many natural variables like lake size, depth, dissolved minerals, water clarity, mean temperature, etc. can affect diversity, in general, a more diverse lake indicates a healthier ecosystem. Perhaps most importantly, plant communities with high diversity also tend to be **more resistant** to invasion by exotic species.

Maximum depth of plants: This indicates the deepest point that vegetation was sampled. In clear lakes, plants may be found at depths of over 20ft, while in stained or turbid locations, they may only be found in a few feet of water. While some species can tolerate very low light conditions, others are only found near the surface. In general, the diversity of the plant community decreases with increased depth.

Mean and median depth of plants: The mean depth of plants indicates the average depth in the water column where plants were sampled. Because a few samples in deep water can skew this data, median depth is also calculated. This tells us that half of the plants sampled were in water shallower than this value, and half were in water deeper than this value.

<u>Number of sites sampled using rope/pole rake:</u> This indicates which rake type was used to take a sample. We use a 20ft pole rake and a 35ft rope rake for sampling.

<u>Average number of species per site:</u> This value is reported using four different considerations. 1) **shallower than maximum depth of plants** indicates the average number of plant species at all sites in the littoral zone. 2) **vegetative sites only** indicate the average number of plants at all sites where plants were found. 3) **native species shallower than maximum depth of plants** and 4) **native species at vegetative sites only** excludes exotic species from consideration.

<u>Species richness:</u> This value indicates the number of different plant species found in and directly adjacent to (on the waterline) the lake. Species richness alone only counts those plants found in the rake survey. The other two values include those seen at a sample point during the survey but not found in the rake, and those that were only seen during the initial boat survey or inter-point. **Note: Per WDNR protocol, filamentous algae, freshwater sponges, aquatic moss and the aquatic liverworts *Riccia fluitans* and *Ricciocarpus natans* are excluded from these totals.**

<u>Average rake fullness:</u> This value is the average rake fullness of all species in the rake. It only takes into account those sites with vegetation (Table 2).

<u>Relative frequency:</u> This value shows a species' frequency relative to all other species. It is expressed as a percentage, and the total of all species' relative frequencies will add up to 100%. Organizing species from highest to lowest relative frequency value gives us an idea of which species are most important within the macrophyte community (Tables 3-5).

Relative frequency example:

Suppose that we sample 100 points and found four species of plants with the following results:

Plant A was located at 70 sites. Its frequency of occurrence is thus 70/100 = 70%
Plant B was located at 50 sites. Its frequency of occurrence is thus 50/100 = 50%
Plant C was located at 20 sites. Its frequency of occurrence is thus 20/100 = 20%
Plant D was located at 10 sites. Its frequency of occurrence is thus 10/100 = 10%

To calculate an individual species' relative frequency, we divide the number of sites a plant is sampled at by the total number of times all plants were sampled. In our example that would be 150 samples (70+50+20+10).

Plant A = 70/150 = .4667 or 46.67%
Plant B = 50/150 = .3333 or 33.33%
Plant C = 20/150 = .1333 or 13.33%
Plant D = 10/150 = .0667 or 6.67%

This value tells us that 46.67% of all plants sampled were Plant A.

Floristic Quality Index (FQI): This index measures the impact of human development on a lake's aquatic plants. The 124 species in the index are assigned a Coefficient of Conservatism (C) which ranges from 1-10. The higher the value assigned, the more likely the plant is to be negatively impacted by human activities relating to water quality or habitat modifications. Plants with low values are tolerant of human habitat modifications, and they often exploit these changes to the point where they may crowd out other species. The FQI is calculated by averaging the conservatism value for each native index species found in the lake during the point-intercept survey** and multiplying it by the square root of the total number of plant species (N) in the lake ($FQI=(\Sigma(c1+c2+c3+\ldots cn)/N)*\sqrt{N}$). Statistically speaking, the higher the index value, the healthier the lake's macrophyte community is assumed to be. Nichols (1999) identified four eco-regions in Wisconsin: Northern Lakes and Forests, North Central Hardwood Forests, Driftless Area and Southeastern Wisconsin Till Plain. He recommended making comparisons of lakes within ecoregions to determine the target lake's relative diversity and health. Lower Vermillion Lake is in the North Central Hardwood Forests Ecoregion (Tables 6-8).

**** Species that were only recorded as visuals or during the boat survey, and species found in the rake that are not included in the index are excluded from FQI analysis.**

Comparison to Past Surveys: We compared data from our 2009, 2016, and 2021 CLP point-intercept surveys (Figure 5) and warm-water point-intercept surveys (Figure 13) to see if there were any significant changes in the lake's vegetation. For individual plant species as well as count data, we used the Chi-square analysis on the WDNR Pre/Posttreatment survey worksheet. For comparing averages (mean species/point and mean rake fullness/point), we used t-tests. Differences were considered significant at $p<0.05$, moderately significant at $p<0.01$ and highly significant at $p<0.001$ (UWEX 2010). It should be noted that when comparing the early spring Curly-leaf pondweed surveys, we used the estimated number of littoral points that were shallow enough to support CLP as the basis for "sample points" (210 in 2009/213 in 2016/207 in 2021). For the warm-water point-intercept surveys, we used the number of littoral points with plants (232 in 2009/212 in 2016/189 in 2021).

RESULTS:

Spring Exotic Species Point-intercept Survey:

Following the establishment of the spring 2021 littoral zone at approximately 10.5ft, we sampled for Curly-leaf pondweed and Eurasian water-milfoil at all points in and adjacent to this zone. CLP was present in the rake at 33 sample points with 34 additional visual sightings. This extrapolated to 4.9% of the entire lake and 16.4% of the spring littoral zone having at least some CLP present. Of these, two rated a rake fullness value of 3, seven were a 2, and the remaining 24 were a 1 for a combined mean rake fullness of 1.33 (Figure 3) (Appendix III). The nine points with a rake fullness of a 2 or a 3 suggested 1.3% of the entire lake and 4.3% of the spring littoral zone had a significant infestation.

Eurasian water-milfoil was present at two points each with a rake fullness of 1 (Figure 4) (Appendix IV). This suggested 0.3% of the lake and 1.0% of the spring littoral zone had EWM present. We also recorded EWM as a visual at a single point and marked nine additional plants inter-point along the southwest shoreline of the lake's northwest bay.

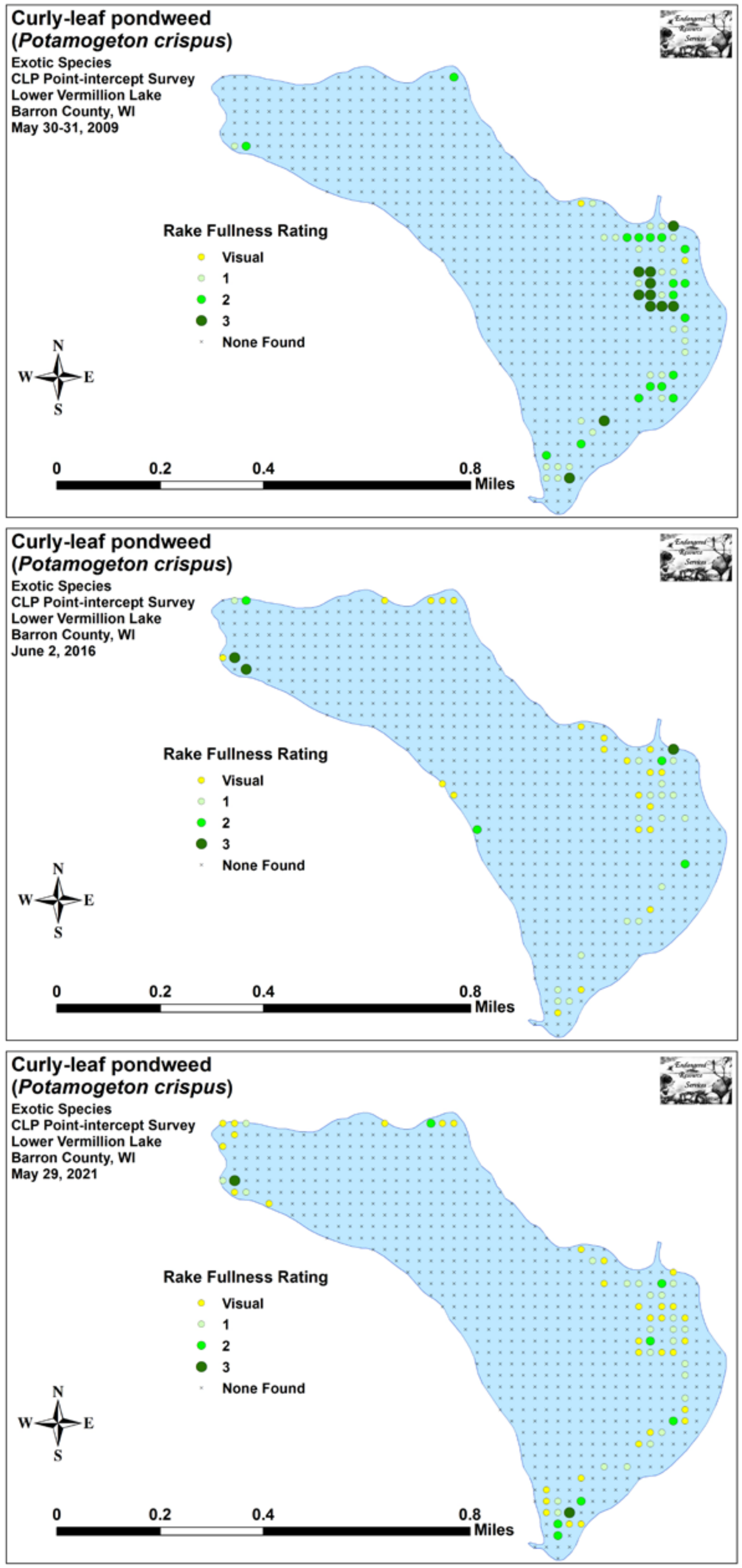
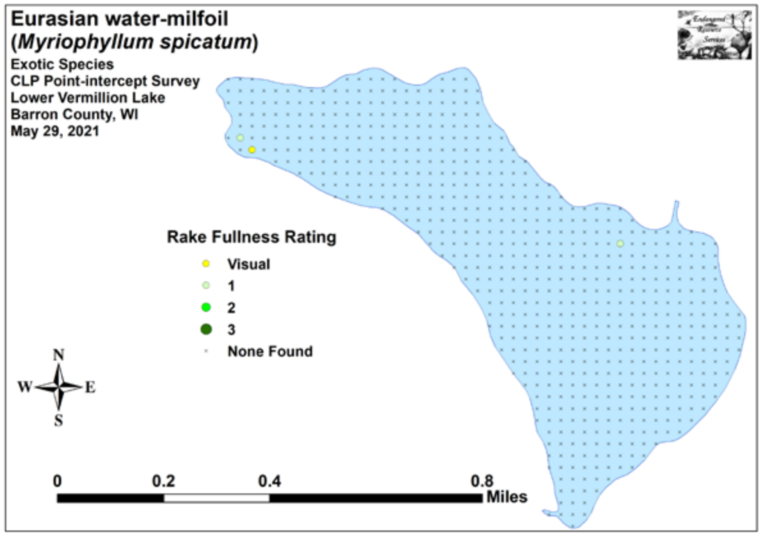


Figure 3: 2009, 2016, and 2021 Late Spring CLP Density and Distribution



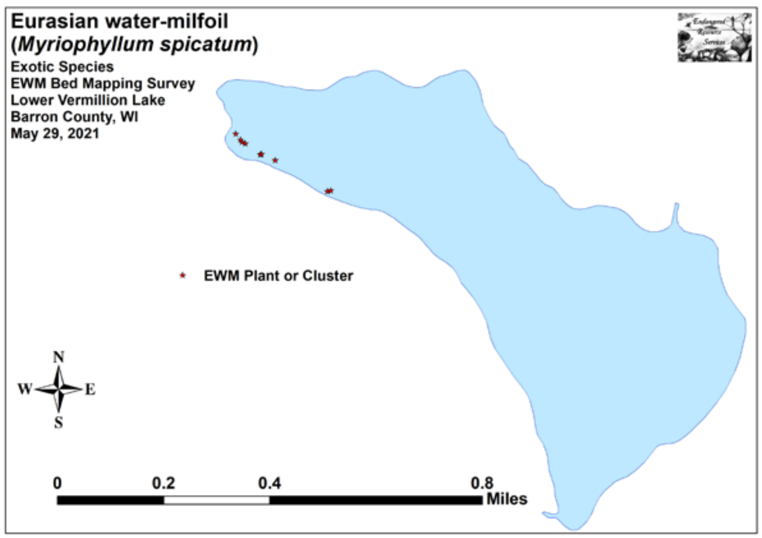


Figure 4: 2021 Late Spring EWM Density and Distribution

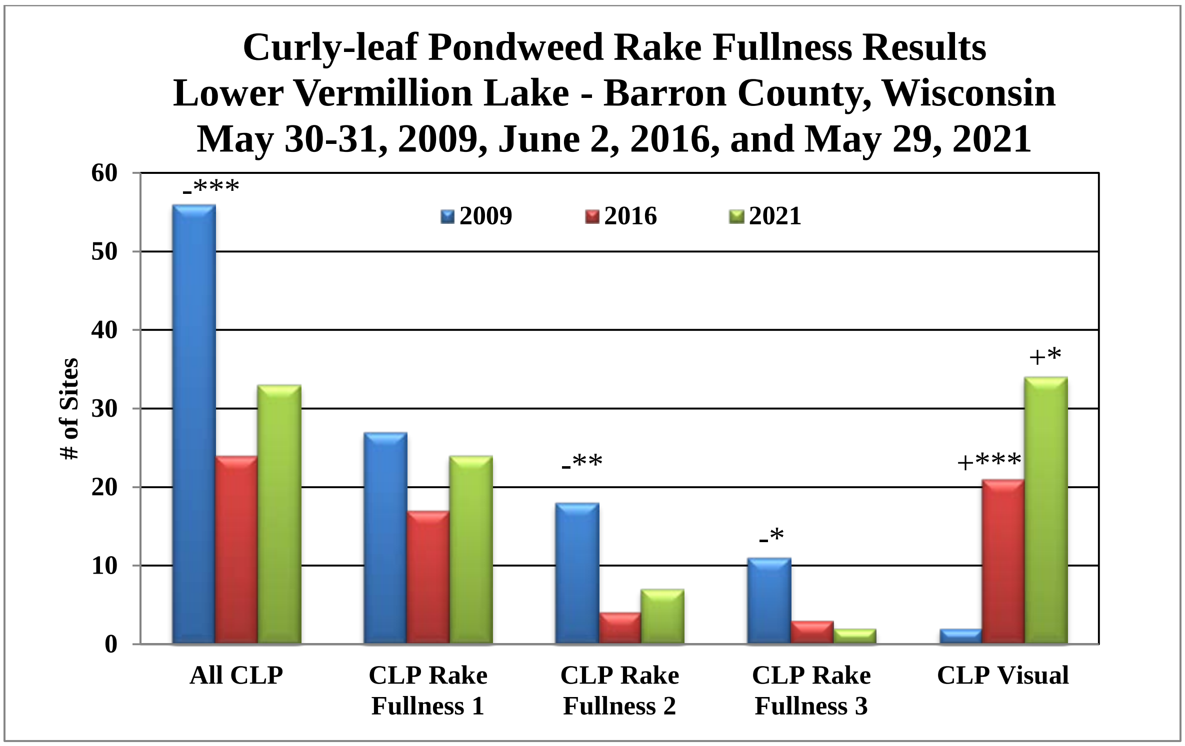
Comparison of Spring CLP and EWM in 2009, 2016, and 2021:

The 2009 spring survey found Curly-leaf pondweed at 56 sites which approximated to 8.3% of the entire lake and 26.7% of the estimated 11.0ft spring littoral zone having CLP present. Of these, we recorded a rake fullness value of 3 at 11 points, a 2 at 18 points, and a value of 1 at 27 points for a mean rake fullness of 1.71. This extrapolated to 4.3% of the lake and 13.8% of the littoral zone having a significant infestation (rake fullness of 2 or 3). We also recorded CLP as a visual at two points (Figure 3) (Appendix III).

In 2016, we found CLP at 24 survey points with 21 additional visual sightings (3.6% of the entire lake/11.3% of the 11.5ft spring littoral zone). We rated three points a rake fullness value of 3, four points a 2, and the remaining 17 points a 1 for a mean rake fullness of 1.42 (Figure 3) (Appendix III). The combined seven points with a rake fullness of a 2 or a 3 suggested 0.9% of the lake and 3.3% of the littoral zone had a significant infestation.

Comparing the 2009 and 2016 surveys found a highly significant decline **(p<0.001)** in total CLP distribution, a moderately significant decline **(p=0.002)** in rake fullness 2, a significant decline **(p=0.03)** in rake fullness 3, and a nearly significant decline (p=0.05) in mean density. Conversely, we noted a highly significant increase **(p<0.001)** in visual sightings (Figure 5).

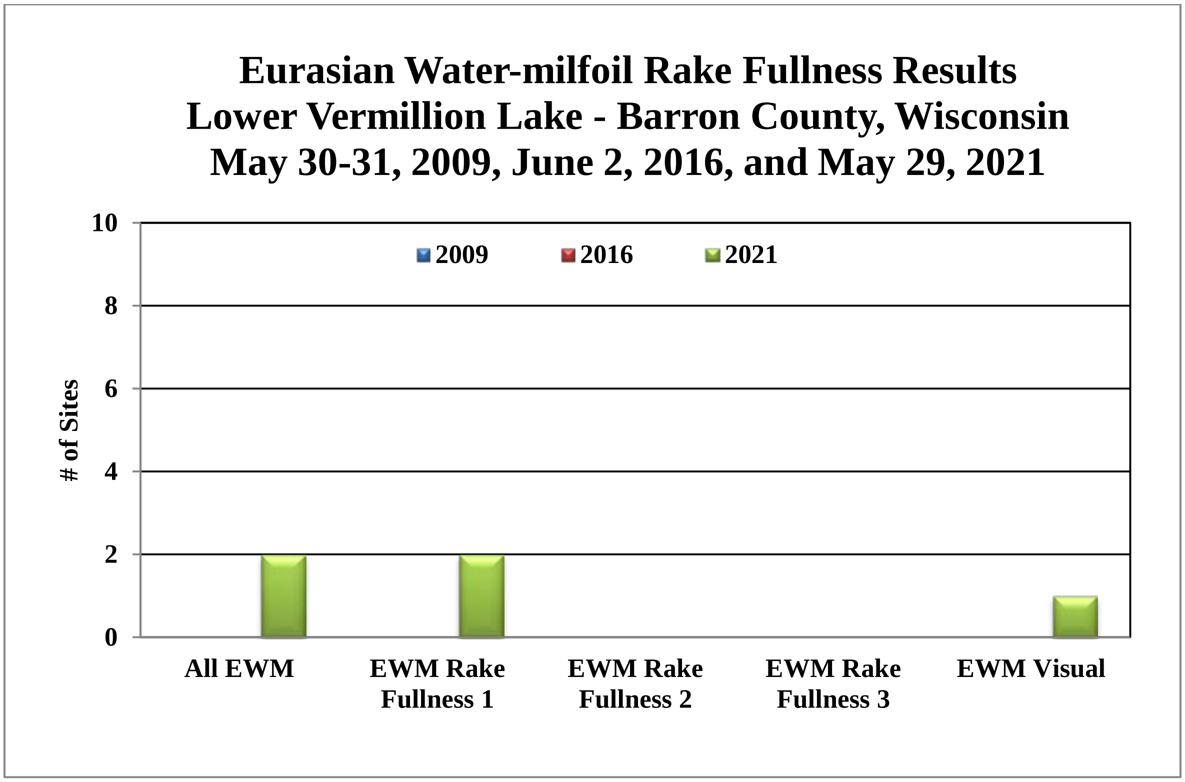
From 2016 to 2021, the only significant change was a further increase in visual sightings **(p<0.05)** (Figure 5). However, when comparing the mean rake fullness from the original spring 2009 survey to 2021, we noted an overall moderately significant decline **(p=0.006)** in density.



Significant differences = * p<0.05, ** p<0.01, *** p<0.001

Figure 5: 2009, 2016, and 2021 Changes in CLP Rake Fullness

Eurasian water-milfoil was not found in the rake during the 2009 or the 2016 spring surveys. None of the categorical increases that we documented in 2021, either pooled or separated, were significant (Figure 6).



Significant differences = * *p*<0.05, ** *p*<0.01, *** *p*<0.001

Figure 6: 2009, 2016, and 2021 Changes in EWM Rake Fullness

Curly-leaf Pondweed Bed Mapping Survey:

In 2021, we mapped eight Curly-leaf pondweed beds that covered 10.85 acres – approximately 5.0% of the lake's surface area (Table 1). This represented a 7.19-acre increase (+196%) from the nine CLP beds on 3.66 acres (1.7% coverage) mapped in 2016. It was also sharply higher than the single CLP bed on 1.10 acres (0.6% coverage) we found during our original 2009 survey (Figure 7) (Appendix III).

Although at face value this increase in CLP bed coverage might appear troubling, we found more overall CLP during the 2009 point-intercept survey than either the 2016 or 2021 surveys. We noted CLP was common and present throughout the lake in 2009, but it was seldom invasive or bed forming. In 2016, CLP was more restricted, but tended to occur at greater densities when it was present. The 2021 survey found CLP beds were common, but they tended to be patchy and seemed unlikely to cause more than minor navigation impairment. During each survey, we noted these beds tended to hold schools of both adult and juvenile panfish potentially making them important early-season vertical habitat.

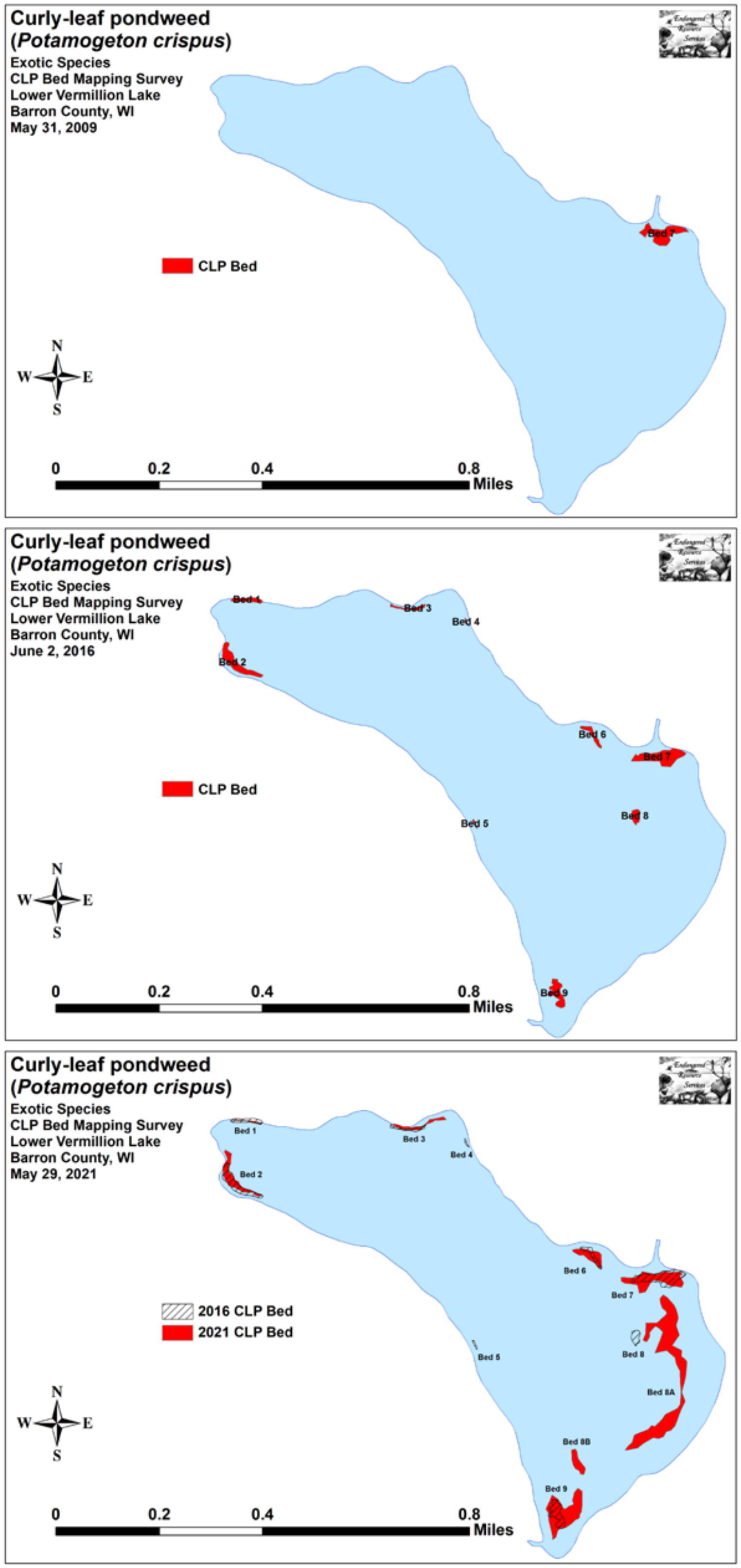


Figure 7: 2009, 2016, and 2021 Late Spring Curly-leaf Pondweed Beds

Descriptions of Past and Present Curly-leaf Pondweed Beds:

Bed 1 – This narrow bed extended along the north shoreline of the northwest bay where it was, at worst, likely only a minor impairment to navigation.

Bed 2 – In 2016, this was easily the worst area on the lake with a solid canopied mat that likely severely impaired navigation for shoreline owners trying to access the lake. Although we found it was nearly identical in size during the 2021 survey, the bed was much more variable in density. We noted a few high-density patches in the southwest corner, but only regular clusters elsewhere. Collectively, it seemed unlikely to be more than a minor impairment to residents.

Beds 3-5 – Bed 3 was a narrow strip along the shoreline that was unlikely to be more than a minor impairment to navigation or lake access. In the areas formerly covered by Beds 4 and 5, we found only a few scattered individual CLP plants. Each of these areas had large numbers of native pondweeds present.

Beds 6 and 7 – Established just southwest and southeast of the inlet from Upper Vermillion Lake, these two beds were more of a collection of patches than a continuous bed. Neither appeared likely to cause more than a minor impairment.

Bed 8 – Located on the outer edge of the littoral zone, we didn't find any canopied CLP in this former bed during the 2021 survey.

Beds 8A and 8B – Much of the eastern bay had patchy CLP growing in the 5-8ft bathymetric ring. These areas accounted for the bulk of the increase in acreage when compared to the 2016 survey, but few if any parts of the beds seemed likely to significantly impair navigation as they generally occurred at low to very low densities.

Bed 9 – Located near the lake outlet, this bed was canopied and moderately dense, but the natural navigation channels around both sides likely made it only a minor navigation impairment. The area was also mixed with high-value native species and in close proximity to Northern wild rice (*Zizania palustris*) making any future active management problematic.

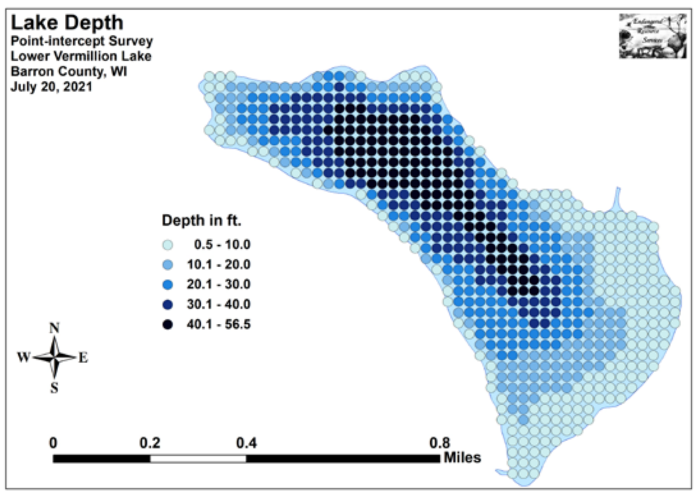
Table 1: Curly-leaf Pondweed Bed Summary
Lower Vermillion Lake - Barron County, Wisconsin – May 29, 2021

Bed Number	2021 Area (Acres)	2016 Area	2009 Area	2016-2021 Change in Area	Est. Range and Mean Rake-full	Depth Range and Mean Depth	Canopied	Potential Nav. Impair.	Field Notes
1	0.08	0.27	0	-0.19	1-3; 2	2-7; 5	Yes	Minor	Too narrow to be mod.
2	0.81	0.83	0	-0.02	<<1-3; 1	2-8; 5	Yes	Minor	Highly variable
3	0.33	0.18	0	0.15	<1-2; 1	2-8; 5	Yes	Minor	Narrow strip along shore
4	0	0.03	0	-0.03	<<<1	-	-	None	Just scattered plants
5	0	0.03	0	-0.03	<<<1	-	-	None	Just scattered plants
6	0.61	0.25	0	0.36	<<<1-2; 1	3-6; 5	Near	Minor	Continuous patches
7	1.62	1.24	1.12	0.38	<<1-3; 1	2-7; 5	Yes	Minor	Collection of clusters
8	0	0.24	0	-0.24	<<<1	-	-	None	Just scattered plants
8A	4.83	0	0	4.83	<<<1-2; <1	5-8; 6	Near	Minor	Continuous plants
8B	0.41	0	0	0.41	<<<1-2; 1	5-7; 6	Near	Minor	Patchy deepwater bed
9	2.17	0.60	0	1.57	<<<1-2; 1	3-6; 5	Yes	Minor	Continuous clusters
Total Acres	**10.85**	**3.66**	**1.12**	**+7.19**					

Warm-water Full Point-intercept Macrophyte Survey:

The Lower Vermillion Lake survey grid contained 671 points (Appendix I) with over half of these occurring in water over 20ft deep. The lake's central basin is a deep bowl with steep north/south sides that drop sharply into 50+ft of water midlake, while the northwest bay near the boat landing/creek inlet slopes more gradually from west to east into the main basin. On the lake's east side where the Vermillion River both enters and exits the lake, the expansive crescent-shaped bay slopes gradually but steadily from the southeast to the northwest into the main basin. The two additional small bays on the north/northwest side of the lake offer limited shallow habitat as they both slope rapidly into deep water (Figure 8) (Appendix V).

Of the 308 points where we could determine the bottom, we characterized the lake's substrate as 40.9% organic and sandy muck (126 points), 36.4% pure sand (112 points), and 22.7% rock (70 points). Thick nutrient-rich organic muck covered the northwest bay near the boat landing and in the river inlet and outlet, while sand and sandy muck dominated the rest of the eastern bay. The majority of the gravel and cobble substrates occurred along the north and south shorelines where wave action and steep drop-offs appeared to be keeping the bottom free of fine sediment (Figure 8) (Appendix V).



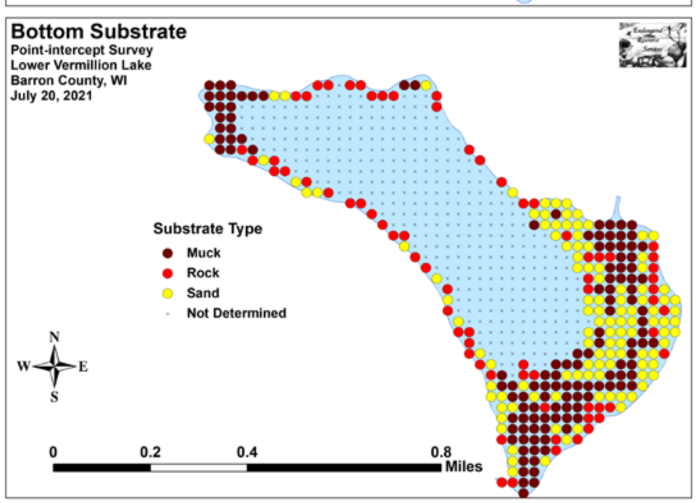


Figure 8: Lake Depth and Bottom Substrate

In 2021, we found plants growing to 14.0ft (up from 13.5ft in 2016/down from 16.0ft in 2009) (Table 2) (Figure 9). The 189 points with vegetation (approximately 28.2% of the entire lake and 76.5% of the littoral zone) was a non-significant decline (*p*=0.17) from 2016 when plants were present at 212 points (31.6% of the bottom/90.2% of the littoral zone). However, it represented a significant decline **(*p*=0.01)** from the 2009 survey when we found plants growing at 232 points (34.6% of the bottom/88.9% of the littoral zone) (Appendix VI).

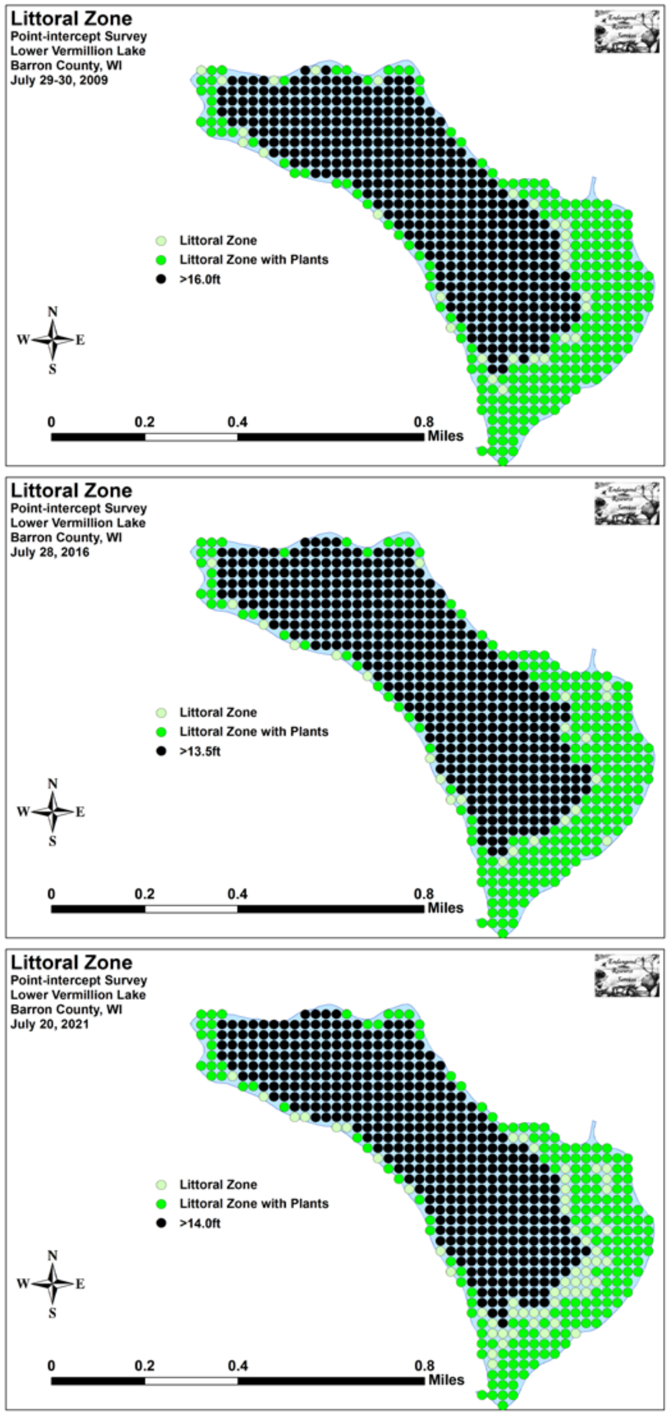


Figure 9: 2009, 2016, and 2021 Littoral Zone

Table 2: Aquatic Macrophyte P/I Survey Summary Statistics
Lower Vermillion Lake - Barron County, Wisconsin
July 29-30, 2009, July 28, 2016, and July 20, 2021

Summary Statistics:	2009	2016	2021
Total number of points sampled	671	671	671
Total number of sites with vegetation	232	212	189
Total number of sites shallower than the max. depth of plants	261	235	247
Freq. of occurrence at sites shallower than max. depth of plants	88.9	90.2	76.5
Simpson Diversity Index	0.93	0.91	0.89
Maximum depth of plants (ft)	16.0	13.5	14.0
Mean depth of plants (ft)	5.5	5.6	4.4
Median depth of plants (ft)	5.0	5.0	4.0
Ave. number of all species per site (shallower than max depth)	3.15	2.73	1.79
Ave. number of all species per site (veg. sites only)	3.55	3.02	2.34
Ave. number of native species per site (shallower than max depth)	3.11	2.72	1.75
Ave. number of native species per site (sites with native veg. only)	3.52	3.01	2.34
Species richness	33	35	34
Species richness (including visuals)	33	38	40
Species richness (including visuals and boat survey)	42	43	44
Mean rake fullness (veg. sites only)	2.43	1.85	2.14

Plant growth in 2021 was slightly skewed to deep water as the mean plant depth of 4.4ft was more than the median depth of 4.0ft. Both of these values were sharply lower than in 2016 and 2009 when the means were 5.6ft/5.5ft and the medians were 5.0ft (Figure 10).

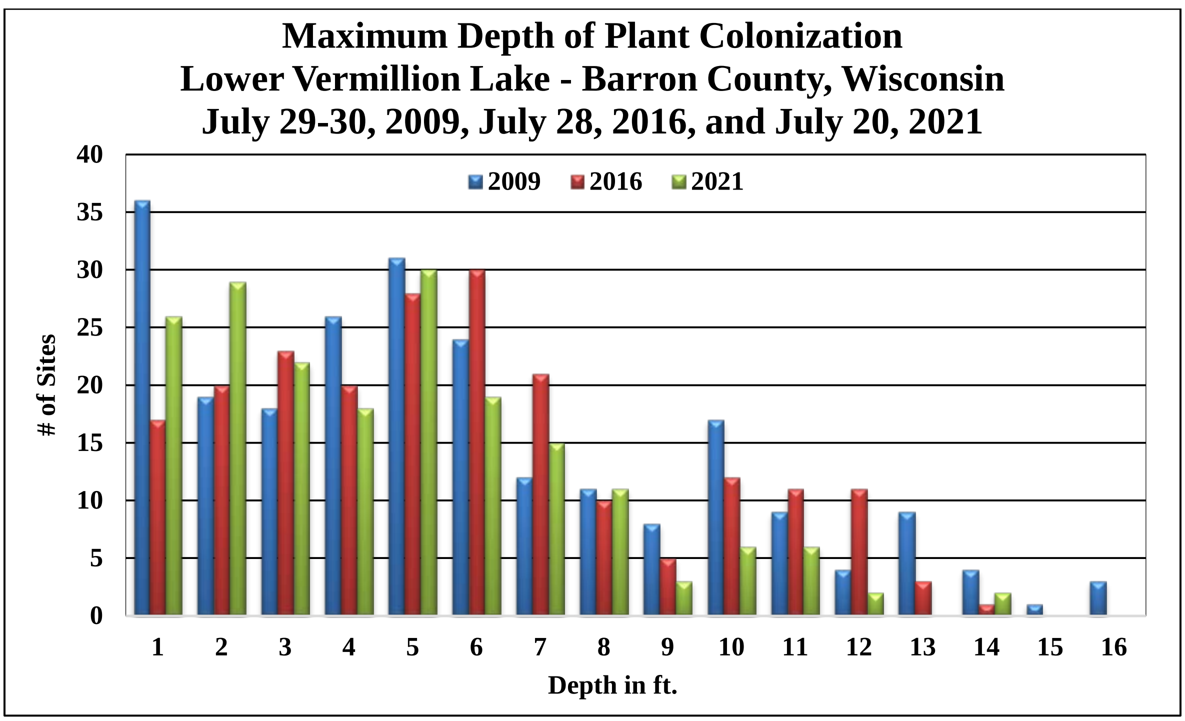


Figure 10: 2009, 2016, and 2021 Plant Colonization Depth Chart

Plant diversity was very high in 2021 with a Simpson Index value of 0.89 – down from 0.91 in 2016 and 0.93 in 2009. Richness was moderate with 34 species found in the rake (similar to 35 in 2016/33 in 2009). This total increased to 44 when including visuals and plants seen during the boat survey (up slightly from 43 in 2016/42 in 2009). Although total richness increased, mean native species richness at sites with native vegetation experienced a highly significant decline **(*p*<0.001)** from 3.52/site in 2009 to 3.01/site in 2016 and a further highly significant decline to 2.34/site in 2021. Visual analysis of the maps showed most of these losses occurred in the east bay (Figure 11) (Appendix VI).

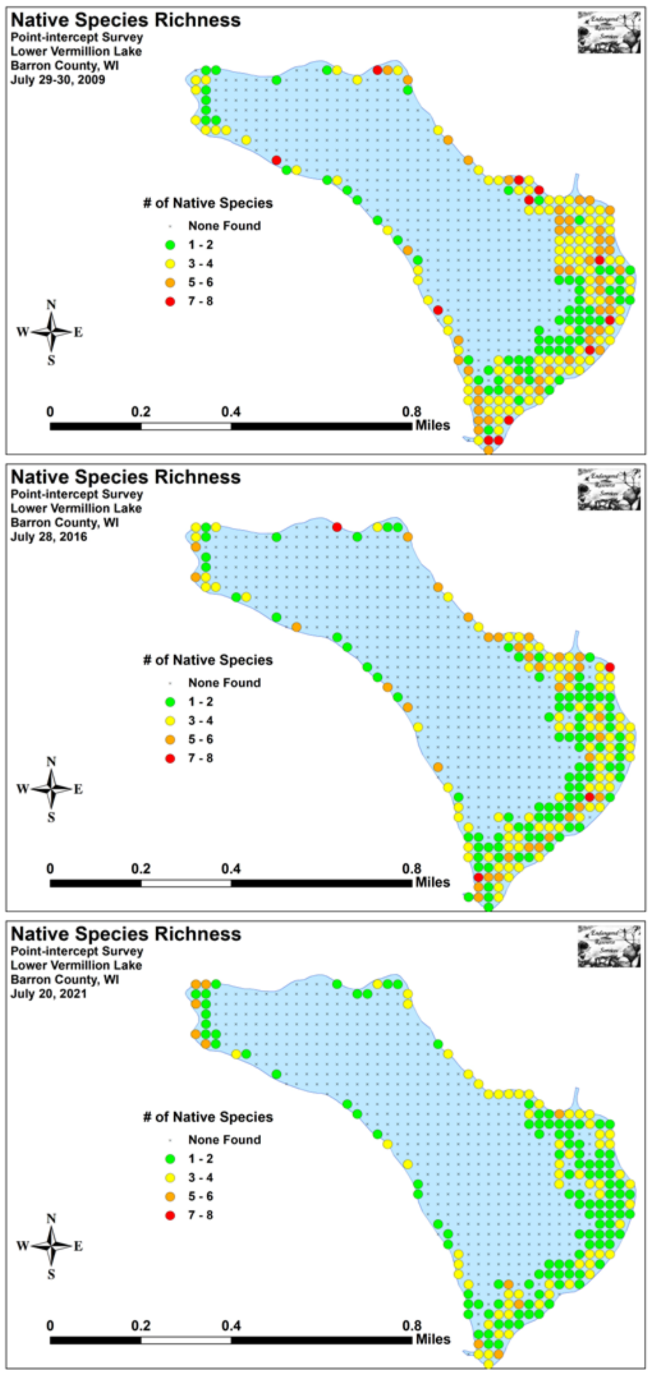


Figure 11: 2009, 2016, and 2021 Native Species Richness

Total rake fullness experienced a highly significant decline **(p<0.001)** from a moderately high 2.43 in 2009 to a low/moderate 1.85 in 2016. We noted these declines appeared to have been a lakewide phenomenon (Figure 12) - potentially due to the poor water clarity experience in 2016 when Secchi readings averaged 6ft – the lowest value since surveys began in 2000 (WDNR 2021). In 2021, this trend reversed as we found a highly significant increase to a moderate mean rake of 2.14 (Appendix VI).

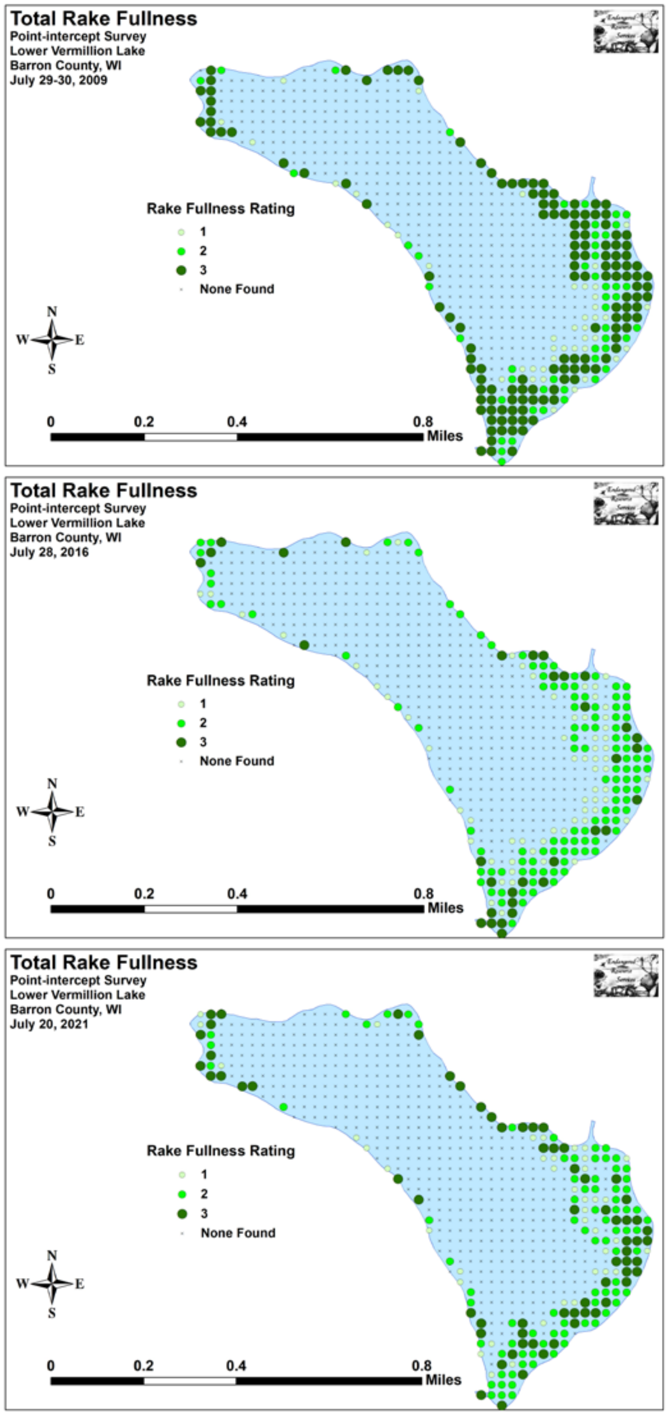


Figure 12: 2009, 2016, and 2021 Total Rake Fullness

Lower Vermillion Lake Plant Community:

The Lower Vermillion Lake ecosystem is home to a moderately rich and highly diverse plant community that is typical of mesotrophic lakes with fair to good water clarity. This community can be subdivided into four distinct zones (emergent, floating-leaf, shallow submergent, and deep submergent) with each zone having its own characteristic functions in the aquatic ecosystem. Depending on the local bottom type (sand, rock, sandy muck, or nutrient-rich organic muck), these zones often had somewhat different species present.

In shallow areas, beds of emergent plants prevent erosion by stabilizing the shoreline, break up wave action, provide a nursery for baitfish and juvenile gamefish, offer shelter for amphibians, and give waterfowl and predatory wading birds like herons a place to hunt. These areas also provide important habitat for invertebrates like dragonflies and mayflies.

Exposed rocky shorelines had few emergents, but in sheltered areas with firm sand and gravel, we found scattered beds of Creeping spikerush (*Eleocharis palustris*), Water horsetail (*Equisetum fluviatile*), Hardstem bulrush (*Schoenoplectus acutus*), and Common bur-reed (*Sparganium eurycarpum*).

Creeping spikerush (Legler 2016)

Water horsetail (Dziak 2005)

Hardstem bulrush (Dziuk 2015)

Common bur-reed (Raymond 2011)

In the lake's bays where there was often a more nutrient-rich organic muck margin, these species were replaced by Wild calla (*Calla palustris*), Bottle brush sedge (*Carex comosa*), Bald spikerush (*Eleocharis erythropoda*), Reed canary grass (*Phalaris arundinacea*), Common arrowhead (*Sagittaria latifolia*), Sessile-fruited arrowhead (*Sagittaria rigida*), Softstem bulrush (*Schoenoplectus tabernaemontani*), and Broad-leaved cattail (*Typha latifolia*). In slightly deeper water over soft muck, especially near the lake outlet, we also noted low to moderate density beds of Northern wild rice.

Wild calla (Pierce 2001)

Bottle-brush sedge (Penta 2009)

Bald spikerush (Schipper 2019)

Reed canary grass (Collins 2009)

Common arrowhead (Young 2006)

Sessile-fruited arrowhead (Chayka 2013)

Softstem bulrush (Schwarz 2011)

Broad-leaved cattail (Raymond 2011)

Northern wild rice flower (Haines 2018)

Maximum density rice in the southeast bay near the outlet 7/20/21

Just beyond the emergents, in muck-bottomed areas in up to 4ft of water, the floating-leaf species Spatterdock (*Nuphar variegata*) and White-water lily (*Nymphaea odorata*) were scattered throughout the lake in sheltered areas, while Water smartweed (*Polygonum amphibium*) tended to be rarer and local. The canopy cover these species provide is often utilized by panfish and bass for protection.

In addition to these larger species, we also documented "duckweeds" floating among both the lilypads and the emergents. Forked duckweed (*Lemna trisulca*) was more scattered than the other species, while Small duckweed (*Lemna minor*), Large duckweed (*Spirodela polyrhiza*), and Common watermeal (*Wolffia columbiana*) tended to be restricted to calm bays where they were found over thick organic muck.

Spatterdock (CBG 2014)

White water lily (Falkner 2009)

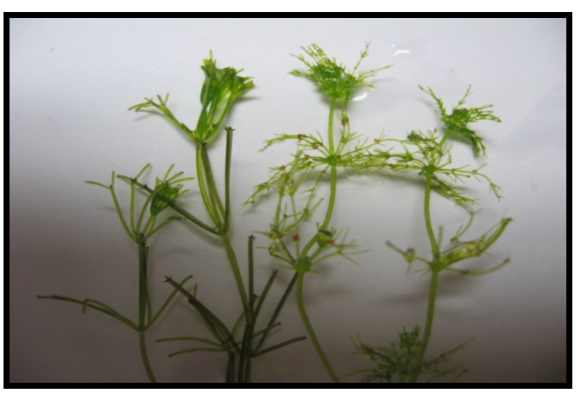
Water smartweed (Someya 2009)

Forked duckweed (Curtis 2010)

Small duckweed and Common watermeal (Kieron 2010)

Large duckweed (Thomas 2014)

The lake's shallow pure sand and gravel areas tended to have low total biomass as these nutrient-poor substrates provide habitat most suited to fine-leaved "isoetid" turf forming species like Muskgrass (*Chara* sp.), Waterwort (*Elatine minima*), Needle spikerush (*Eleocharis acicularis*), Spiny-spored quillwort (*Isoetes echinospora*), Slender naiad (*Najas flexilis*), White water crowfoot (*Ranunculus aquatilis*), Grass-leaved arrowhead (*Sagittaria graminea*), and Sago pondweed (*Stuckenia pectinata*). Near the inlet immediately south of the northwest public boat landing over soft silt, we also found Horned pondweed (*Zannichellia palustris*) – a species not previously know to occur in Barron County. All of these shallow submergent species, along with the emergents, stabilize the bottom and prevent wave action erosion.



Muskgrass (Penuh 2007)

Waterwort (Fewless 2005)

Needle spikerush (Fewless 2005)

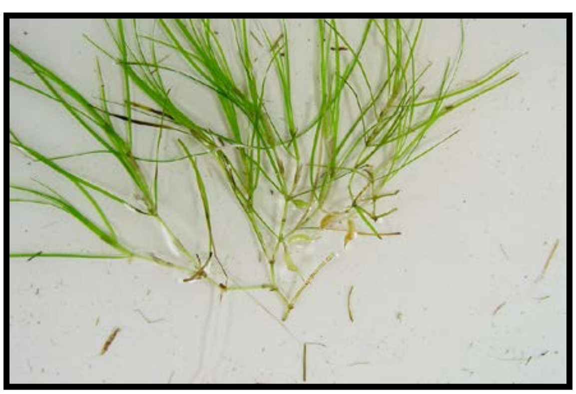
Spiny-spored quillwort (Fewless 2005)

Slender naiad (Apipp 2009)

White water crowfoot (Wasser 2014)

Grass-leaved arrowhead (Flaigg 2003)

Sago pondweed (Hilty 2012)



Horned pondweed (Cameron 2020)

Close-up of Horned pondweed with banana-shaped fruits (Fischer 2019)

In areas with sandy muck, in water up to 10ft deep, we found scattered patches of Water star-grass (*Heteranthera dubia*), Northern water-milfoil (*Myriophyllum sibiricum*), Fries' pondweed (*Potamogeton friesii*), Variable pondweed (*Potamogeton gramineus*), Illinois pondweed (*Potamogeton illinoensis*), Clasping-leaf pondweed (*Potamogeton richardsonii*), Stiff pondweed (*Potamogeton strictifolius*), and Wild celery (*Vallisneria americana*). The roots, shoots, and seeds of these species are heavily utilized by both resident and migratory waterfowl for food. They also provide important habitat for the lake's fish throughout their lifecycles, as well as a myriad of invertebrates like scuds, dragonfly and mayfly nymphs, and snails.

Water star-grass (Mueller 2010)

Northern water-milfoil (Berg 2007)

Fries' pondweed (End 2012)

Variable pondweed (Koshere 2002)

Illinois pondweed (Dziuk 2017)

Clasping-leaf pondweed (Cameron 2013)

Stiff pondweed (Cameron 2016)

Wild celery (Dalvi 2009)

Organic muck areas in water greater than 4ft were dominated by Coontail (*Ceratophyllum demersum*) and Common waterweed (*Elodea canadensis*) with lesser amounts of Eurasian water-milfoil, Curly-leaf pondweed, Large-leaf pondweed (*Potamogeton amplifolius*) (not seen in 2021, but common in 2009 and 2016), White-stem pondweed (*Potamogeton praelongus*), Small pondweed (*Potamogeton pusillus*), and Flat-stem pondweed (*Potamogeton zosteriformis*). Predatory fish like the lake's Northern pike (*Esox lucius*) are often found along the edges of these beds waiting in ambush.

Coontail (Hassler 2011)

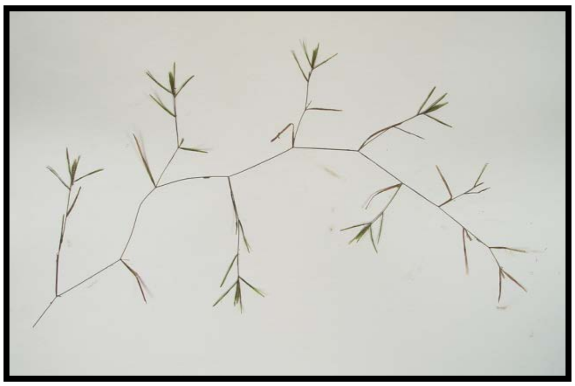
Common waterweed (Pinkka 2013)

Eurasian water-milfoil (Berg 2007)

Curly-leaf pondweed (USGS 2019)

Large-leaf pondweed (Dziuk 2018)

White-stem pondweed (Fewless 2005)



Small pondweed (Cameron 2013)

Flat-stem pondweed (Dziuk 2019)

Comparison of Native Macrophyte Species in 2009, 2016, and 2021:

The July 2009 survey found Coontail, Flat-stem pondweed, Slender naiad, and Wild celery were the most common macrophyte species (Table 3). They were present at 49.14%, 47.84%, 29.74%, and 29.74% of survey points with vegetation respectively and accounted for 44.11% of the total relative frequency. Muskgrass (8.14%), Clasping-leaf pondweed (6.08%), Northern water-milfoil (5.47%), and Fries' pondweed (5.47%) also had relative frequencies over 4.0% (Maps for all species found in July 2009 are located in the project folder).

In July 2016, we identified Coontail, Flat-stem pondweed, Wild celery, and Fries' pondweed as the most common species. Present at 51.42%, 41.51%, 33.02%, and 29.72% of sites with vegetation (Table 4), they accounted for 51.48% of the total relative frequency. Slender naiad (9.36%) and Muskgrass (6.71%) also had relative frequencies over 4.0% (Maps for all species found in July 2016 are located in the project folder).

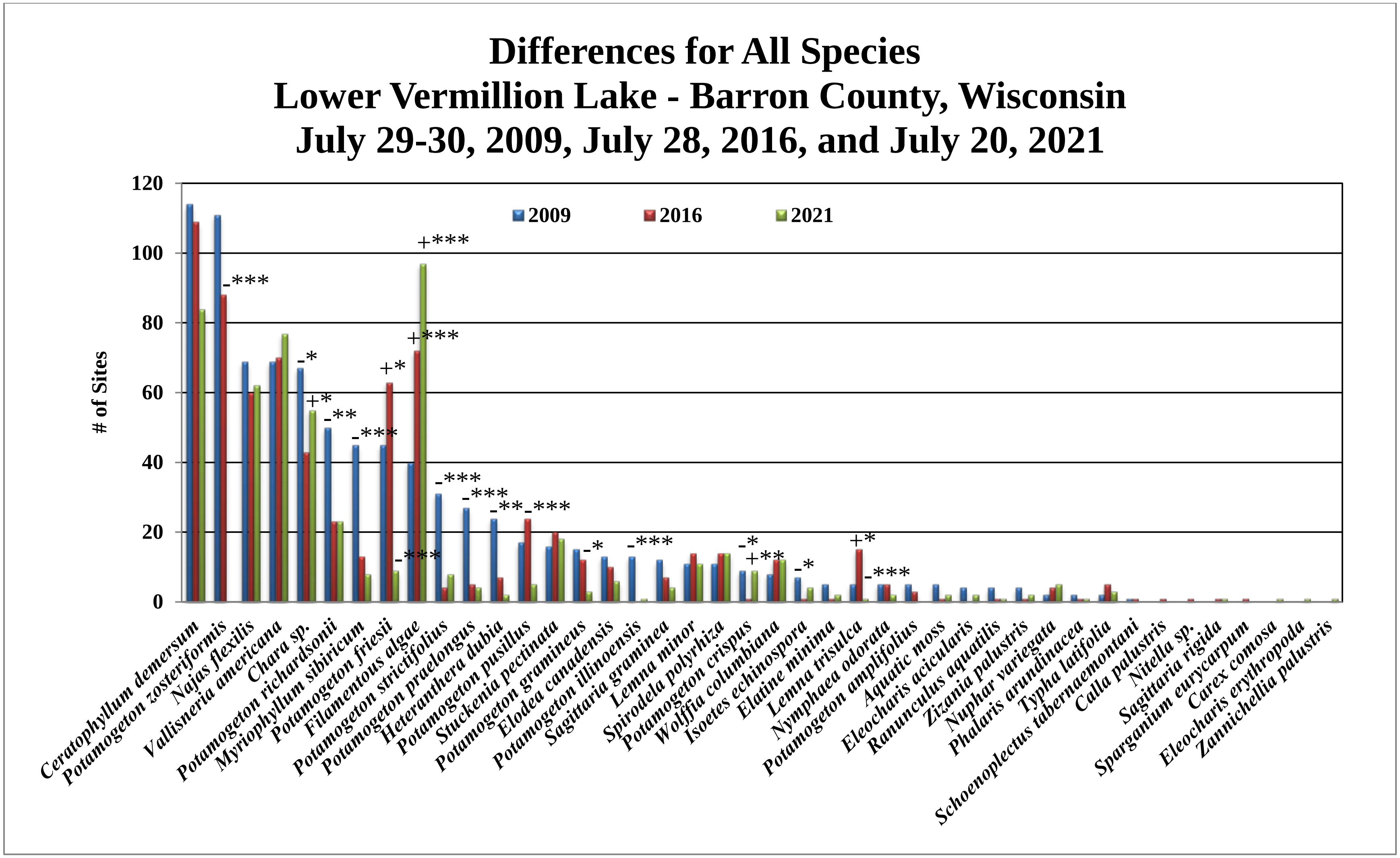
Lakewide, 12 species showed significant changes in distribution from 2009 to 2016 (Figure 13). Northern water-milfoil, Stiff pondweed, White-stem pondweed, and Illinois pondweed suffered highly significant declines **(p<0.001)**; Clasping-leaf pondweed **(p=0.002)** and Water star-grass **(p=0.002)** experienced moderately significant declines; and Muskgrass **(p=0.03)**, Curly-leaf pondweed **(p=0.02)**, and Spiny-spored quillwort **(p=0.04)** demonstrated significant declines. Conversely, filamentous algae saw a highly significant increase **(p<0.001)**; and Fries' pondweed **(p=0.01)** and Forked duckweed **(p=0.01)** showed significant increases.

When considering the changes from 2009 to 2016, the decline in Northern water-milfoil may have been at least partially tied to the herbicide treatment of EWM as these two sister species are both sensitive to 2-4,D. The expansion of filamentous algae and Forked duckweed might also have been in response to nutrients being released from decomposing plants posttreatment; however, monocots like the many pondweeds that experienced declines, are not expected to be impacted by the treatment. These losses may have simply been tied to the poor water clarity observed in 2016 or some other change in annual growing conditions.

The 2021 survey identified Coontail (44.44% of points with vegetation), Wild celery (40.74%), Slender naiad (32.80%), and Muskgrass (29.10%) as the most common species with a combined relative frequency of 62.90% (Table 5). Clasping-leaf pondweed (5.20%) and Sago pondweed (4.07%) also had relative frequencies over 4.00% (Density and distribution maps for all native plant species found in 2021 are located in Appendix VI).

From 2016 to 2021, eight species underwent significant changes in distribution (Figure 13). Flat-stem pondweed, Fries' pondweed, Small pondweed, and Forked duckweed suffered highly significant declines **(p<0.001)**; and Variable pondweed saw a significant decline **(p=0.03)**. Conversely filamentous algae saw a highly significant increase **(p<0.001)**; Curly-leaf pondweed underwent a moderately significant increase **(p=0.006)**; and Muskgrass had a significant increase **(p=0.04)**.

The majority of the changes seen from 2016 to 2021 appear to have occurred on the outer edge of the littoral zone. The especially poor clarity we documented during the July 2021 survey may be the best explanation of why species like Small pondweed and Fries' pondweed had already set turions and senesced. It might also be at least a partial reason for why the Flat-stem pondweed population crashed.



Significant differences = * *p*<0.05, ** *p*<0.01, * *p*<0.001**

Figure 13: Macrophytes Showing Significant Changes from 2009-2016-2021

Table 3: Frequencies and Mean Rake Sample of Aquatic Macrophytes
Lower Vermillion Lake - Barron County, Wisconsin
July 29-30, 2009

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Ceratophyllum demersum	Coontail	114	13.85	49.14	43.68	1.83	1
Potamogeton zosteriformis	Flat-stem pondweed	111	13.49	47.84	42.53	1.95	8
Najas flexilis	Slender naiad	69	8.38	29.74	26.44	1.94	3
Vallisneria americana	Wild celery	69	8.38	29.74	26.44	1.70	2
Chara sp.	Muskgrass	67	8.14	28.88	25.67	2.39	1
Potamogeton richardsonii	Clasping-leaf pondweed	50	6.08	21.55	19.16	1.60	11
Myriophyllum sibiricum	Northern water-milfoil	45	5.47	19.40	17.24	1.73	13
Potamogeton friesii	Fries' pondweed	45	5.47	19.40	17.24	1.49	1
	Filamentous algae	40	*	17.24	15.33	1.80	0
Potamogeton strictifolius	Stiff pondweed	31	3.77	13.36	11.88	1.06	1
Potamogeton praelongus	White-stem pondweed	27	3.28	11.64	10.34	1.41	9
Heteranthera dubia	Water star-grass	24	2.92	10.34	9.20	1.38	1
Potamogeton pusillus	Small pondweed	17	2.07	7.33	6.51	1.12	1
Stuckenia pectinata	Sago pondweed	16	1.94	6.90	6.13	1.56	6
Potamogeton gramineus	Variable pondweed	15	1.82	6.47	5.75	1.33	0
Elodea canadensis	Common waterweed	13	1.58	5.60	4.98	1.77	1
Potamogeton illinoensis	Illinois pondweed	13	1.58	5.60	4.98	1.38	2
Sagittaria graminea	Grass-leaved arrowhead	12	1.46	5.17	4.60	2.00	3
Lemna minor	Small duckweed	11	1.34	4.74	4.21	1.45	0
Spirodela polyrhiza	Large duckweed	11	1.34	4.74	4.21	1.82	0
Potamogeton crispus	**Curly-leaf pondweed**	**9**	**1.09**	**3.88**	**3.45**	**1.22**	**2**
Wolffia columbiana	Common watermeal	8	0.97	3.45	3.07	1.63	0
Isoetes echinospora	Spiny spored-quillwort	7	0.85	3.02	2.68	2.00	1

* Excluded from relative frequency analysis **Exotic species in bold**

Table 3 (continued): Frequencies and Mean Rake Sample of Aquatic Macrophytes
Lower Vermillion Lake - Barron County, Wisconsin
July 29-30, 2009

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Elatine minima	Waterwort	5	0.61	2.16	1.92	2.00	3
Lemna trisulca	Forked duckweed	5	0.61	2.16	1.92	1.00	0
Nymphaea odorata	White water lily	5	0.61	2.16	1.92	2.00	0
Potamogeton amplifolius	Large-leaf pondweed	5	0.61	2.16	1.92	1.60	0
	Aquatic moss	5	*	2.16	1.92	1.60	0
Eleocharis acicularis	Needle spikerush	4	0.49	1.72	1.53	1.50	1
Ranunculus aquatilis	White water crowfoot	4	0.49	1.72	1.53	1.50	2
Zizania palustris	Northern wild rice	4	0.49	1.72	1.53	1.75	1
Nuphar variegata	Spatterdock	2	0.24	0.86	0.77	2.50	3
Phalaris arundinacea	**Reed canary grass**	**2**	**0.24**	**0.86**	**0.77**	**2.00**	**0**
Typha latifolia	Broad-leaved cattail	2	0.24	0.86	0.77	1.50	0
Schoenoplectus tabernaemontani	Softstem bulrush	1	0.12	0.43	0.38	3.00	0
Carex comosa	Bottle-brush sedge	***	***	***	***	***	***
Eleocharis erythropoda	Bald spikerush	***	***	***	***	***	***
Eleocharis palustris	Creeping spikerush	***	***	***	***	***	***
Equisetum fluviatile	Water horsetail	***	***	***	***	***	***
Juncus tenuis	Greater poverty rush	***	***	***	***	***	***
Myriophyllum spicatum	**Eurasian water-milfoil**	*******	*******	*******	*******	*******	*******
Polygonum amphibium	Water smartweed	***	***	***	***	***	***
Sagittaria latifolia	Common arrowhead	***	***	***	***	***	***
Sparganium eurycarpum	Common bur-reed	***	***	***	***	***	***

* Excluded from relative frequency analysis   *** Boat survey only   **Exotic species in bold**

Table 4: Frequencies and Mean Rake Sample of Aquatic Macrophytes
Lower Vermillion Lake - Barron County, Wisconsin
July 28, 2016

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Ceratophyllum demersum	Coontail	109	17.00	51.42	46.38	1.40	2
Potamogeton zosteriformis	Flat-stem pondweed	88	13.73	41.51	37.45	1.40	6
	Filamentous algae	72	*	33.96	30.64	1.39	0
Vallisneria americana	Wild celery	70	10.92	33.02	29.79	1.37	3
Potamogeton friesii	Fries' pondweed	63	9.83	29.72	26.81	1.25	3
Najas flexilis	Slender naiad	60	9.36	28.30	25.53	1.48	2
Chara sp.	Muskgrass	43	6.71	20.28	18.30	1.81	0
Potamogeton pusillus	Small pondweed	24	3.74	11.32	10.21	1.13	1
Potamogeton richardsonii	Clasping-leaf pondweed	23	3.59	10.85	9.79	1.30	7
Stuckenia pectinata	Sago pondweed	20	3.12	9.43	8.51	1.50	5
Lemna trisulca	Forked duckweed	15	2.34	7.08	6.38	1.00	0
Lemna minor	Small duckweed	14	2.18	6.60	5.96	1.64	0
Spirodela polyrhiza	Large duckweed	14	2.18	6.60	5.96	1.36	0
Myriophyllum sibiricum	Northern water-milfoil	13	2.03	6.13	5.53	1.00	0
Potamogeton gramineus	Variable pondweed	12	1.87	5.66	5.11	1.00	2
Wolffia columbiana	Common watermeal	12	1.87	5.66	5.11	1.25	0
Elodea canadensis	Common waterweed	10	1.56	4.72	4.26	1.40	0
Heteranthera dubia	Water star-grass	7	1.09	3.30	2.98	1.29	1
Sagittaria graminea	Grass-leaved arrowhead	7	1.09	3.30	2.98	1.29	1
Nymphaea odorata	White water lily	5	0.78	2.36	2.13	2.20	0
Potamogeton praelongus	White-stem pondweed	5	0.78	2.36	2.13	1.00	0
Typha latifolia	Broad-leaved cattail	5	0.78	2.36	2.13	2.60	0

* Excluded from relative frequency analysis

Table 4 (continued): Frequencies and Mean Rake Sample of Aquatic Macrophytes
Lower Vermillion Lake - Barron County, Wisconsin
July 28, 2016

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Nuphar variegata	Spatterdock	4	0.62	1.89	1.70	2.25	6
Potamogeton strictifolius	Stiff pondweed	4	0.62	1.89	1.70	1.00	2
Potamogeton amplifolius	Large-leaf pondweed	3	0.47	1.42	1.28	1.67	0
Calla palustris	Wild calla	1	0.16	0.47	0.43	1.00	0
Elatine minima	Waterwort	1	0.16	0.47	0.43	2.00	0
Isoetes echinospora	Spiny spored-quillwort	1	0.16	0.47	0.43	1.00	1
Nitella sp.	Nitella	1	0.16	0.47	0.43	1.00	0
Phalaris arundinacea	**Reed canary grass**	**1**	**0.16**	**0.47**	**0.43**	**2.00**	**1**
Potamogeton crispus	**Curly-leaf pondweed**	**1**	**0.16**	**0.47**	**0.43**	**1.00**	**0**
Ranunculus aquatilis	White water crowfoot	1	0.16	0.47	0.43	2.00	0
Sagittaria rigida	Sessile-fruited arrowhead	1	0.16	0.47	0.43	2.00	0
Schoenoplectus tabernaemontani	Softstem bulrush	1	0.16	0.47	0.43	1.00	0
Sparganium eurycarpum	Common bur-reed	1	0.16	0.47	0.43	2.00	1
Zizania palustris	Northern wild rice	1	0.16	0.47	0.43	2.00	1
	Aquatic moss	1	*	0.47	0.43	2.00	0
Carex comosa	Bottle brush sedge	**	**	**	**	**	1
Eleocharis erythropoda	Bald spikerush	**	**	**	**	**	1
Sagittaria latifolia	Common arrowhead	**	**	**	**	**	1
Eleocharis palustris	Creeping spikerush	***	***	***	***	***	***
Equisetum fluviatile	Water horsetail	***	***	***	***	***	***
Myriophyllum spicatum	**Eurasian water-milfoil**	*****	*****	*****	*****	*****	*****
Polygonum amphibium	Water smartweed	***	***	***	***	***	***
Potamogeton illinoensis	Illinois pondweed	***	***	***	***	***	***

* Excluded from relative frequency analysis   ** Visual only   *** Boat survey only   **Exotic species in bold**

Table 5: Frequencies and Mean Rake Sample of Aquatic Macrophytes
Lower Vermillion Lake - Barron County, Wisconsin
July 20, 2021

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
	Filamentous algae	97	*	51.32	39.27	1.49	0
Ceratophyllum demersum	Coontail	84	19.00	44.44	34.01	1.67	1
Vallisneria americana	Wild celery	77	17.42	40.74	31.17	1.61	2
Najas flexilis	Slender naiad	62	14.03	32.80	25.10	1.76	4
Chara sp.	Muskgrass	55	12.44	29.10	22.27	2.11	2
Potamogeton richardsonii	Clasping-leaf pondweed	23	5.20	12.17	9.31	1.30	8
Stuckenia pectinata	Sago pondweed	18	4.07	9.52	7.29	1.39	9
Spirodela polyrhiza	Large duckweed	14	3.17	7.41	5.67	1.43	0
Wolffia columbiana	Common watermeal	12	2.71	6.35	4.86	1.33	0
Lemna minor	Small duckweed	11	2.49	5.82	4.45	1.09	0
Potamogeton crispus	**Curly-leaf pondweed**	**9**	**2.04**	**4.76**	**3.64**	**1.00**	**4**
Potamogeton friesii	Fries' pondweed	9	2.04	4.76	3.64	1.56	3
Myriophyllum sibiricum	Northern water-milfoil	8	1.81	4.23	3.24	1.50	9
Potamogeton strictifolius	Stiff pondweed	8	1.81	4.23	3.24	1.13	3
Elodea canadensis	Common waterweed	6	1.36	3.17	2.43	1.83	0
Nuphar variegata	Spatterdock	5	1.13	2.65	2.02	1.60	5
Potamogeton pusillus	Small pondweed	5	1.13	2.65	2.02	1.20	0
Isoetes echinospora	Spiny spored-quillwort	4	0.90	2.12	1.62	1.25	1
Potamogeton praelongus	White-stem pondweed	4	0.90	2.12	1.62	1.50	2
Sagittaria graminea	Grass-leaved arrowhead	4	0.90	2.12	1.62	1.25	5
Potamogeton gramineus	Variable pondweed	3	0.68	1.59	1.21	1.00	2
Typha latifolia	Broad-leaved cattail	3	0.68	1.59	1.21	2.00	3

* Excluded from relative frequency analysis **Exotic species in bold**

Table 5 (continued): Frequencies and Mean Rake Sample of Aquatic Macrophytes
Lower Vermillion Lake - Barron County, Wisconsin
July 20, 2021

Species	Common Name	Total Sites	Relative Freq.	Freq. in Veg.	Freq. in Lit.	Mean Rake	Visual Sight.
Elatine minima	Waterwort	2	0.45	1.06	0.81	1.50	0
Eleocharis acicularis	Needle spikerush	2	0.45	1.06	0.81	2.00	0
Heteranthera dubia	Water star-grass	2	0.45	1.06	0.81	1.50	1
Nymphaea odorata	White water lily	2	0.45	1.06	0.81	2.00	1
Zizania palustris	Northern wild rice	2	0.45	1.06	0.81	1.50	0
	Aquatic moss	2	*	1.06	0.81	1.00	0
Carex comosa	Bottle brush sedge	1	0.23	0.53	0.40	1.00	0
Eleocharis erythropoda	Bald spikerush	1	0.23	0.53	0.40	3.00	1
Lemna trisulca	Forked duckweed	1	0.23	0.53	0.40	1.00	0
Phalaris arundinacea	**Reed canary grass**	**1**	**0.23**	**0.53**	**0.40**	**3.00**	**0**
Potamogeton illinoensis	Illinois pondweed	1	0.23	0.53	0.40	1.00	1
Ranunculus aquatilis	White water crowfoot	1	0.23	0.53	0.40	1.00	1
Sagittaria rigida	Sessile-fruited arrowhead	1	0.23	0.53	0.40	1.00	0
Zannichellia palustris	Horned pondweed	1	0.23	0.53	0.40	1.00	1
Calla palustris	Wild calla	**	**	**	**	**	1
Myriophyllum spicatum	**Eurasian water-milfoil**	**	**	**	**	**	**1**
Potamogeton zosteriformis	Flat-stem pondweed	**	**	**	**	**	3
Sagittaria latifolia	Common arrowhead	**	**	**	**	**	1
Schoenoplectus tabernaemontani	Softstem bulrush	**	**	**	**	**	1
Sparganium eurycarpum	Common bur-reed	**	**	**	**	**	1
Eleocharis palustris	Creeping spikerush	***	***	***	***	***	***
Equisetum fluviatile	Water horsetail	***	***	***	***	***	***
Polygonum amphibium	Water smartweed	***	***	***	***	***	***
Schoenoplectus acutus	Hardstem bulrush	***	***	***	***	***	***

* Excluded from relative frequency analysis   ** Visual only   *** Boat survey only   **Exotic species in bold**

Coontail, the most common macrophyte species in 2009, 2016, and 2021, was present in most areas with sandy and organic muck (Figure 14). From 2009 to 2016, it saw a non-significant decline (p=0.63) in distribution (114 sites in 2009/109 sites in 2016) and a highly significant decline in density **(p<0.001)** (mean rake fullness of 1.83 in 2009/1.40 in 2016). In 2021, we documented a further non-significant decline (p=0.16) in distribution to 84 sites; however, the density underwent a moderately significant increase **(p=0.004)** to a mean rake fullness of 1.67.

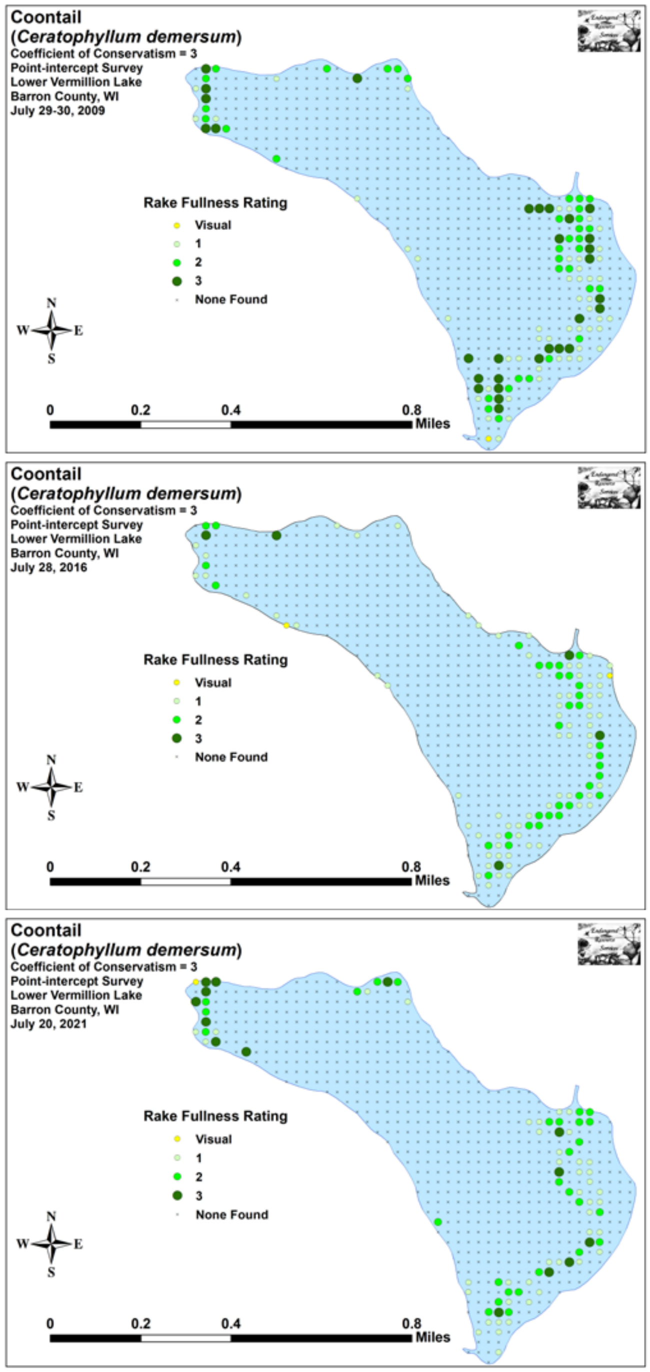


Figure 14: 2009, 2016, and 2021 Coontail Density and Distribution

Flat-stem pondweed was the second most common species in both 2009 and 2016 (Figure 15). Similar to Coontail, it experienced a non-significant decline (p=0.18) in distribution (111 sites in 2009/88 sites in 2016) and a highly significant decline in density **(p<0.001)** (mean rake of 1.95 in 2009/1.40 in 2016). The 2021 survey documented a complete population crash as we didn't find the species in the rake at any points. The reason for these highly significant declines **(p<0.001)** in both density and distribution is unknown.

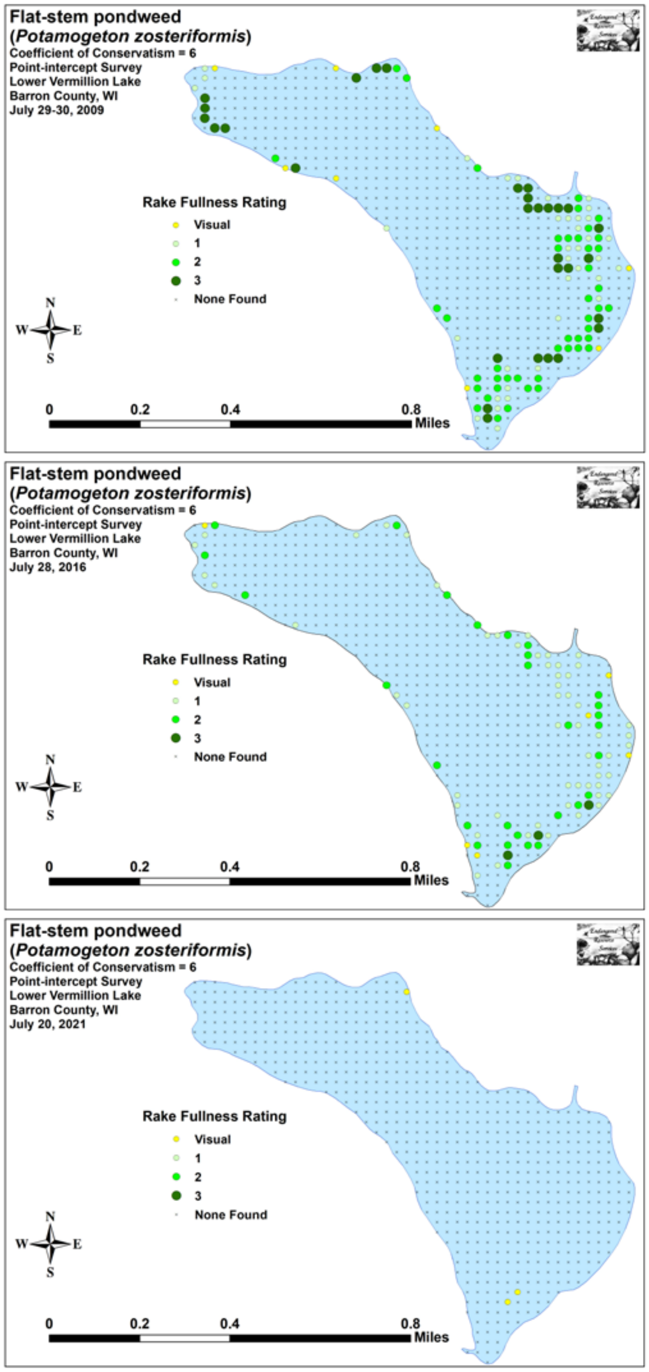


Figure 15: 2009, 2016, and 2021 Flat-stem Pondweed Density and Distribution

We found Wild celery was the third most common species in both 2009 and 2016 (Figure 16). Over this time, it was almost unchanged (*p*=0.46) in distribution (69 sites in 2009/70 sites in 2016) but saw a moderately significant decline **(*p*=0.002)** in density (mean rake of 1.70 in 2009/1.37 in 2016). In 2021, it was the second most widely-distributed species after undergoing a non-significant increase (*p*=0.11) in distribution (77 sites) and a significant increase **(*p* =0.01)** in density (mean rake of 1.61).

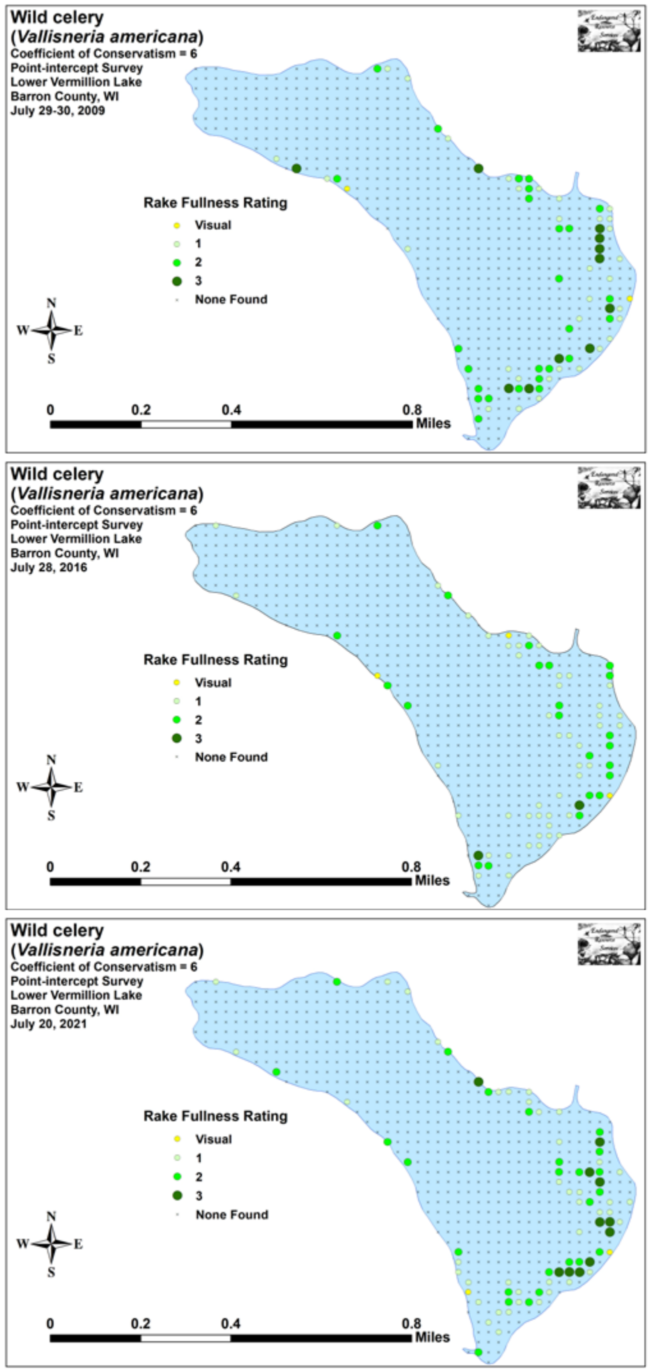


Figure 16: 2009, 2016, and 2021 Wild Celery Density and Distribution

Northern water-milfoil was the seventh most common species during the 2009 survey when it dominated many areas of the east bay (Figure 17). After experiencing highly significant declines **(p<0.001)** in both distribution (45 sites in 2009/13 sites in 2016) and density (mean rake fullness of 1.73 in 2009/1.00 in 2016), it was just the 13th most common species in 2016. The 2021 survey documented a further non-significant decline in distribution (eight sites) and a nearly significant increase (p=0.05) in density (mean rake 1.50). Despite the decline in distribution, it increased its community rank to the 12th most common species.

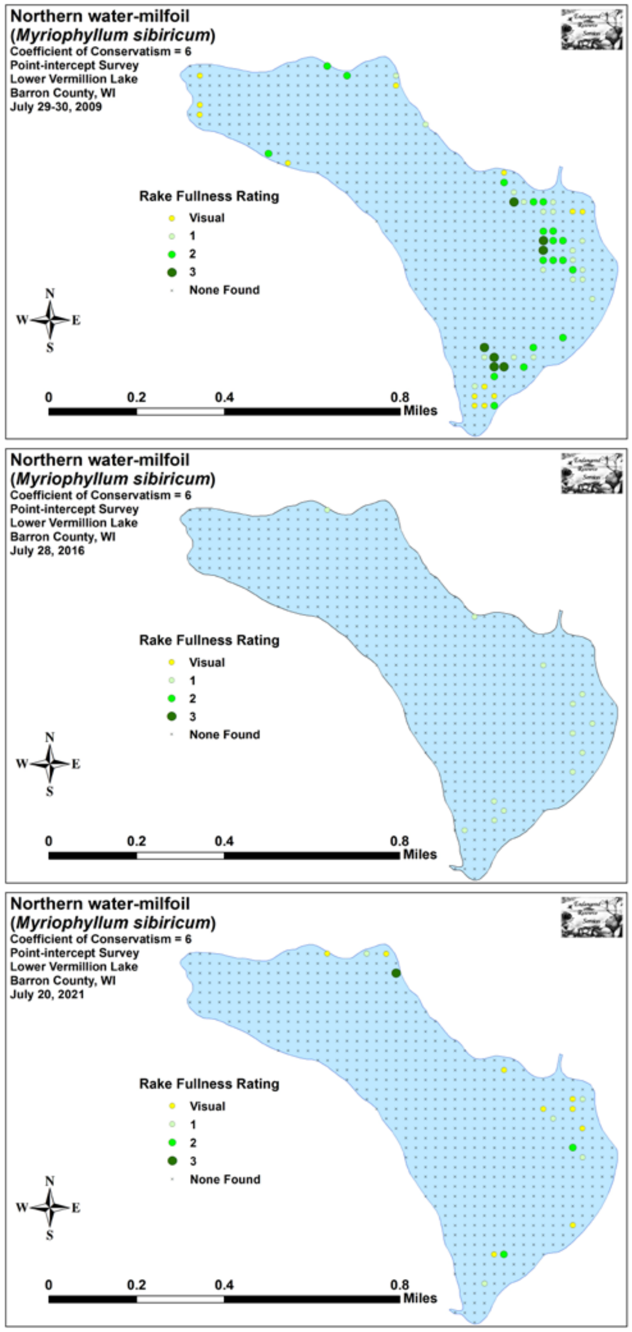


Figure 17: 2009, 2016, and 2021 Northern Water-milfoil Density and Distribution

Comparison of Northern Wild Rice in 2009, 2016, and 2021:

In 2009, we documented Northern wild rice at four points (mean rake 1.75) in a patchwork bed that covered nearly one acre in the southeast outlet bay (Figure 18). The 2016 survey found rice at a single point, and we noted the population had shrunk to just a few hundred goose-cropped plants that were scattered along the shoreline. In 2021, rice occurred at two points with a mean rake of 1.75, and we observed a general thickening of the total bed relative to 2016 levels (see report cover showing maximum rice density).

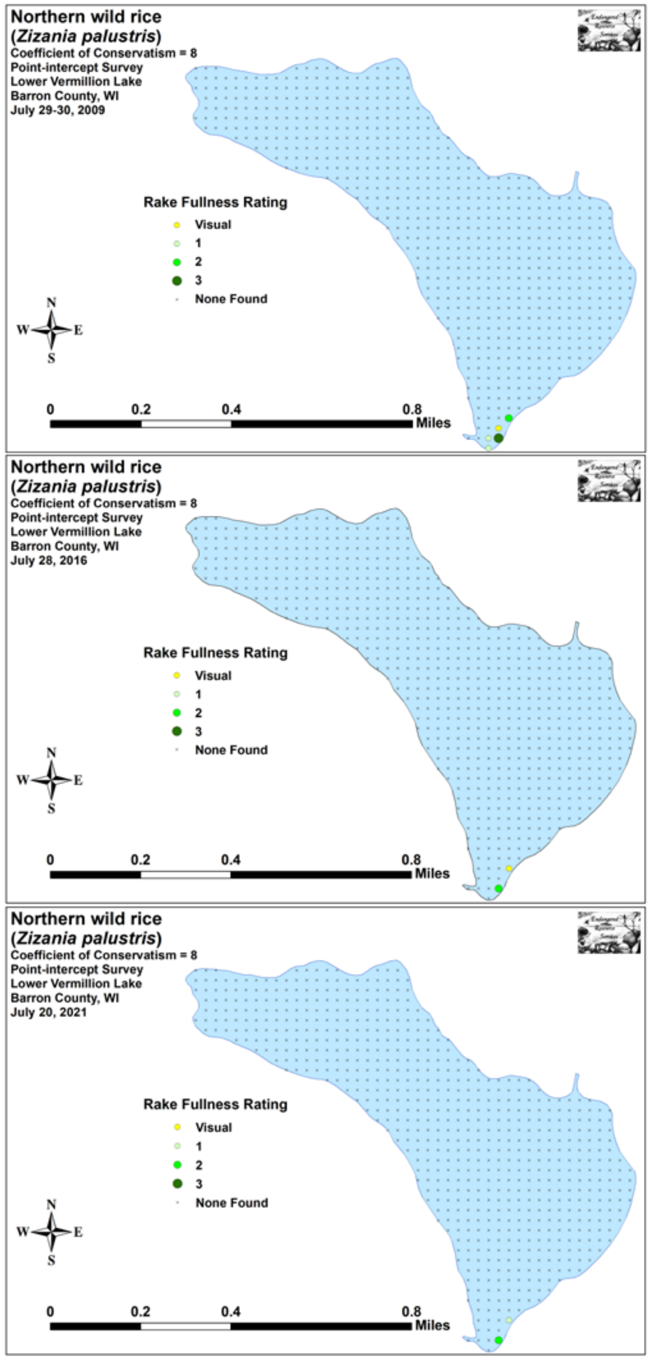


Figure 18: 2009, 2016, and 2021 Northern Wild Rice Density and Distribution

Comparison of Floristic Quality Indexes in 2009, 2016, and 2021:

In 2009, we identified a total of 31 **native index species** in the rake during the point-intercept survey (Table 6). They produced a mean Coefficient of Conservatism of 6.0 and a Floristic Quality Index of 33.4.

Table 6: Floristic Quality Index of Aquatic Macrophytes
Lower Vermillion Lake - Barron County, Wisconsin
July 29-30, 2009

Species	Common Name	C
Ceratophyllum demersum	Coontail	3
Chara sp.	Muskgrass	7
Elatine minima	Waterwort	9
Eleocharis acicularis	Needle spikerush	5
Elodea canadensis	Common waterweed	3
Heteranthera dubia	Water star-grass	6
Isoetes echinospora	Spiny-spored quillwort	8
Lemna minor	Small duckweed	4
Lemna trisulca	Forked duckweed	6
Myriophyllum sibiricum	Northern water-milfoil	6
Najas flexilis	Slender naiad	6
Nuphar variegata	Spatterdock	6
Nymphaea odorata	White water lily	6
Potamogeton amplifolius	Large-leaf pondweed	7
Potamogeton friesii	Fries' pondweed	8
Potamogeton gramineus	Variable pondweed	7
Potamogeton illinoensis	Illinois pondweed	6
Potamogeton praelongus	White-stem pondweed	8
Potamogeton pusillus	Small pondweed	7
Potamogeton richardsonii	Clasping-leaf pondweed	5
Potamogeton strictifolius	Stiff pondweed	8
Potamogeton zosteriformis	Flat-stem pondweed	6
Ranunculus aquatilis	White water crowfoot	8
Sagittaria graminea	Grass-leaved arrowhead	9
Schoenoplectus tabernaemontani	Softstem bulrush	4
Spirodela polyrhiza	Large duckweed	5
Stuckenia pectinata	Sago pondweed	3
Typha latifolia	Broad-leaved cattail	1
Vallisneria americana	Wild celery	6
Wolffia columbiana	Common watermeal	5
Zizania palustris	Northern wild rice	8
N		**31**
Mean C		**6.0**
FQI		**33.4**

Our 2016 point-intercept survey found a total of 33 **native index plants** in the rake. They produced a mean Coefficient of Conservatism of 6.2 and a Floristic Quality Index of 35.5 (Table 7).

Table 7: Floristic Quality Index of Aquatic Macrophytes
Lower Vermillion Lake - Barron County, Wisconsin
July 28, 2016

Species	Common Name	C
Calla palustris	Wild calla	9
Ceratophyllum demersum	Coontail	3
Chara sp.	Muskgrass	7
Elatine minima	Waterwort	9
Elodea canadensis	Common waterweed	3
Heteranthera dubia	Water star-grass	6
Isoetes echinospora	Spiny-spored quillwort	8
Lemna minor	Small duckweed	4
Lemna trisulca	Forked duckweed	6
Myriophyllum sibiricum	Northern water-milfoil	6
Najas flexilis	Slender naiad	6
Nitella sp.	Nitella	7
Nuphar variegata	Spatterdock	6
Nymphaea odorata	White water lily	6
Potamogeton amplifolius	Large-leaf pondweed	7
Potamogeton friesii	Fries' pondweed	8
Potamogeton gramineus	Variable pondweed	7
Potamogeton praelongus	White-stem pondweed	8
Potamogeton pusillus	Small pondweed	7
Potamogeton richardsonii	Clasping-leaf pondweed	5
Potamogeton strictifolius	Stiff pondweed	8
Potamogeton zosteriformis	Flat-stem pondweed	6
Ranunculus aquatilis	White water crowfoot	8
Sagittaria graminea	Grass-leaved arrowhead	9
Sagittaria rigida	Sessile-fruited arrowhead	8
Schoenoplectus tabernaemontani	Softstem bulrush	4
Sparganium eurycarpum	Common bur-reed	5
Spirodela polyrhiza	Large duckweed	5
Stuckenia pectinata	Sago pondweed	3
Typha latifolia	Broad-leaved cattail	1
Vallisneria americana	Wild celery	6
Wolffia columbiana	Common watermeal	5
Zizania palustris	Northern wild rice	8
N		**33**
Mean C		**6.2**
FQI		**35.5**

The 2021 point-intercept survey had 32 **native index plants** in the rake. They produced a mean Coefficient of Conservatism of 6.0 and a Floristic Quality Index of 33.9 (Table 8). Nichols (1999) reported an average mean C for the North Central Hardwood Forests Region of 5.6 putting Lower Vermillion Lake above average for this part of the state. The FQI was also well above the median FQI of 20.9 for the North Central Hardwood Forests (Nichols 1999).

Table 8: Floristic Quality Index of Aquatic Macrophytes Lower Vermillion Lake - Barron County, Wisconsin July 20, 2021

Species	Common Name	C
Carex comosa	Bottle brush sedge	5
Ceratophyllum demersum	Coontail	3
Chara sp.	Muskgrass	7
Elatine minima	Waterwort	9
Eleocharis acicularis	Needle spikerush	5
Eleocharis erythropoda	Bald spikerush	3
Elodea canadensis	Common waterweed	3
Heteranthera dubia	Water star-grass	6
Isoetes echinospora	Spiny-spored quillwort	8
Lemna minor	Small duckweed	4
Lemna trisulca	Forked duckweed	6
Myriophyllum sibiricum	Northern water-milfoil	6
Najas flexilis	Slender naiad	6
Nuphar variegata	Spatterdock	6
Nymphaea odorata	White water lily	6
Potamogeton friesii	Fries' pondweed	8
Potamogeton gramineus	Variable pondweed	7
Potamogeton illinoensis	Illinois pondweed	6
Potamogeton praelongus	White-stem pondweed	8
Potamogeton pusillus	Small pondweed	7
Potamogeton richardsonii	Clasping-leaf pondweed	5
Potamogeton strictifolius	Stiff pondweed	8
Ranunculus aquatilis	White water crowfoot	8
Sagittaria graminea	Grass-leaved arrowhead	9
Sagittaria rigida	Sessile-fruited arrowhead	8
Spirodela polyrhiza	Large duckweed	5
Stuckenia pectinata	Sago pondweed	3
Typha latifolia	Broad-leaved cattail	1
Vallisneria americana	Wild celery	6
Wolffia columbiana	Common watermeal	5
Zannichellia palustris	Horned pondweed	7
Zizania palustris	Northern wild rice	8
N		**32**
Mean C		**6.0**
FQI		**33.9**

Comparison of Filamentous Algae in 2009, 2016, and 2021:

Filamentous algae are normally associated with excessive nutrients in the water column from such things as runoff, internal nutrient recycling, and failed septic systems. In 2009, these algae were located at 40 points with a mean rake fullness of 1.80 (Figure 19). The 2016 survey documented them at 72 points with a mean rake of 1.39 – a highly significant increase **(p<0.001)** in distribution, but a moderately significant decline **(p=0.02)** in density. The 2021 survey found a further highly significant increase **(p<0.001)** in distribution to 97 sites, and a non-significant increase (p=0.13) in density to a mean rake of 1.49.

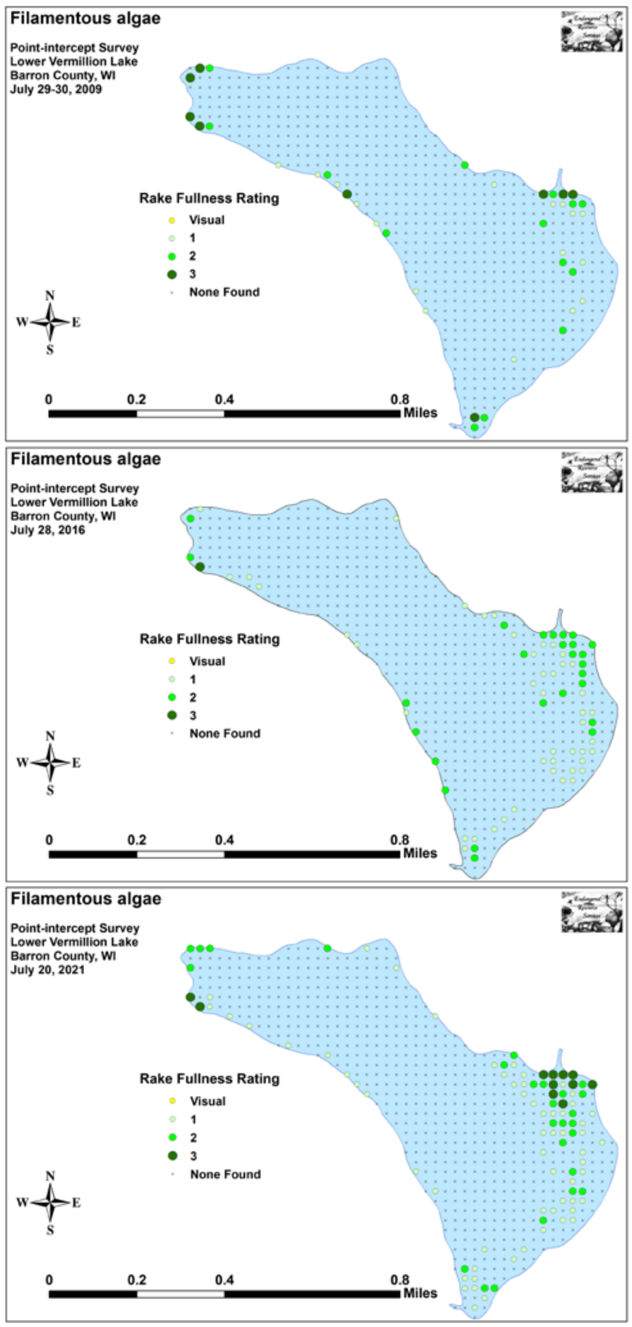


Figure 19: 2009, 2016, and 2021 Filamentous Algae Density and Distribution

Comparison of Midsummer CLP in 2009, 2016, and 2021:

Curly-leaf pondweed normally completes its annual life cycle by late June, and most plants have set turions and senesced by July. In 2009, CLP was still present at nine points with a mean rake fullness 1.22 (Figure 20). During the 2016 survey, we found a single CLP plant at a single point – a significant decline **(*p*=0.02)** in distribution. The 2021 survey found CLP at nine points all with a rake fullness of 1. This was a moderately significant increase **(*p*=0.006)** in distribution compared to 2016 (Appendix VII).

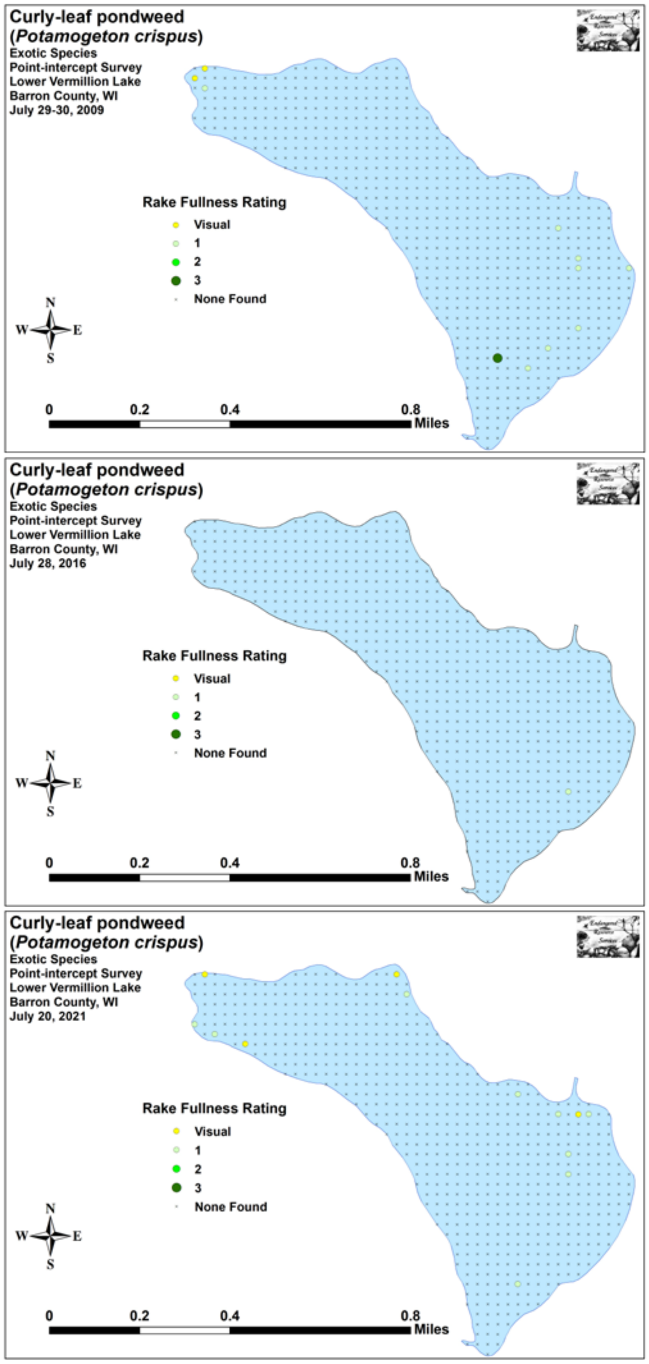


Figure 20: 2009, 2016, and 2021 Midsummer Curly-leaf Pondweed Density and Distribution

Comparison of Midsummer EWM in 2009, 2016, and 2021:

In July 2009, we didn't find Eurasian water-milfoil in the rake at any point, and the only plants seen were near the public boat landing – the site of the original infestation. The 2016 July survey produced similar results as we again found and rake removed a handful of plants near the public boat landing and along the southern shoreline of the northwest bay. In July 2021, we didn't find EWM in the rake at any point, but it was a visual at a single location near the boat landing (Figure 21) (Appendix VII).

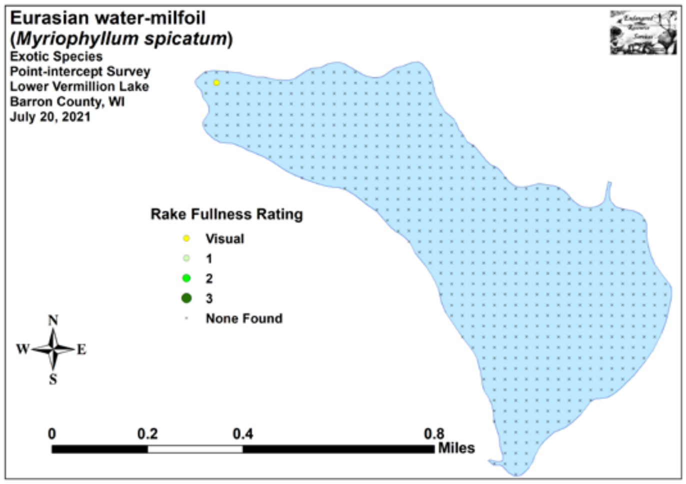


Figure 21: 2021 Eurasian Water-milfoil Density and Distribution

Other Exotic Plant Species:

Other than Curly-leaf pondweed and Eurasian water-milfoil, the only other exotic species found on Lower Vermillion Lake was Reed canary grass. Despite only being recorded in the rake at one point (Figure 18), it was often a dominant plant just beyond the lakeshore (Appendix VII). We noticed patches in adjacent wetlands and next to mowed and otherwise disturbed shorelines. A ubiquitous plant in the state, there's likely little that can be done about it (For more information on a sampling of aquatic exotic invasive plant species, see Appendix VIII).

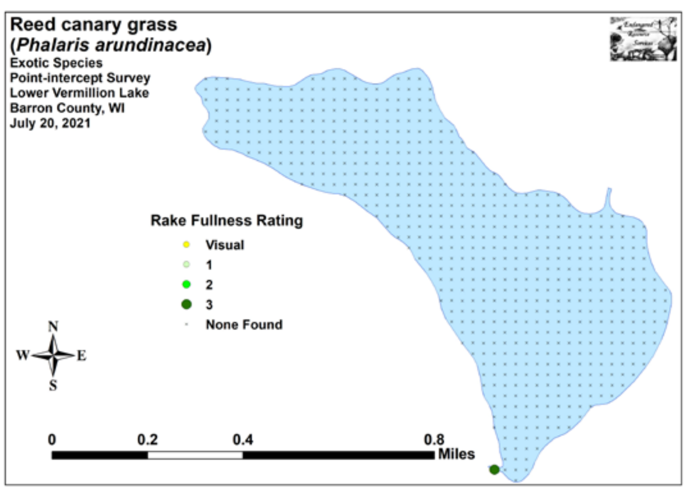


Figure 22: 2021 Reed Canary Grass Density and Distribution

DISCUSSION AND CONSIDERATIONS FOR MANAGEMENT:

Native Aquatic Macrophytes and Eurasian Water-milfoil Management:

Lower Vermillion Lake continues to have a rich and diverse native plant community. Unfortunately, Eurasian water-milfoil will pose a continued threat to that diversity and the resource as a whole moving forward as it is unlikely that EWM will ever be totally eliminated from the lake. This threat to the lake's native plant communities is a significant one because they are the base of the aquatic food pyramid, provide habitat for fish and other aquatic organisms, are important food sources for waterfowl and other wildlife, stabilize the shoreline, and work to improve water clarity by absorbing excess nutrients from the water.

The current management program has been successful at keeping EWM levels low. Hopefully, with continued manual removal and targeted small-scale treatments, the VLA can maintain or even further reduce EWM from its current low levels while simultaneously minimizing impacts on the lake's native plants.

Potential Future Curly-leaf Pondweed Management:

Although Curly-leaf pondweed is an exotic species, in most years it appears to play a generally minor role in the lake's ecosystem. Because of this, active management may not be required - at least in all but the worst places. Much like algae and duckweeds, CLP tends to grow best in areas with excessive nutrients in the water; especially when there is also bottom disturbance. To help limit CLP's opportunities to thrive and expand, all lake residents are encouraged to evaluating how their shoreline practices may be impacting the lake. Simple things like establishing or maintaining their own buffer strip of native vegetation along the lakeshore to prevent erosion, building rain gardens, bagging grass clippings, switching to a phosphorus-free fertilizer or preferably eliminating fertilizer near the lake altogether, collecting pet waste, and disposing of the ash from fire pits away from the lakeshore can all significantly reduce the amount of nutrients entering the lake. Avoiding motor starts in water less than 4ft deep can also maintain native vegetation and prevent the stirring up of nutrient-rich sediment. By limiting nutrient inputs, residents not only create less than ideal growing conditions for CLP, but also promote better water clarity and quality by limiting algal growth. Hopefully, a greater understanding of how all property owners can have lake-wide impacts will result in more people taking appropriate conservation actions.

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WDNR. [online]. 2021. Citizen Lake Monitoring Water Quality Data Report for Lower Vermillion Lake. http://dnr.wi.gov/lakes/lakepages/LakeDetail.aspx?wbic=2098200 (2021, December)

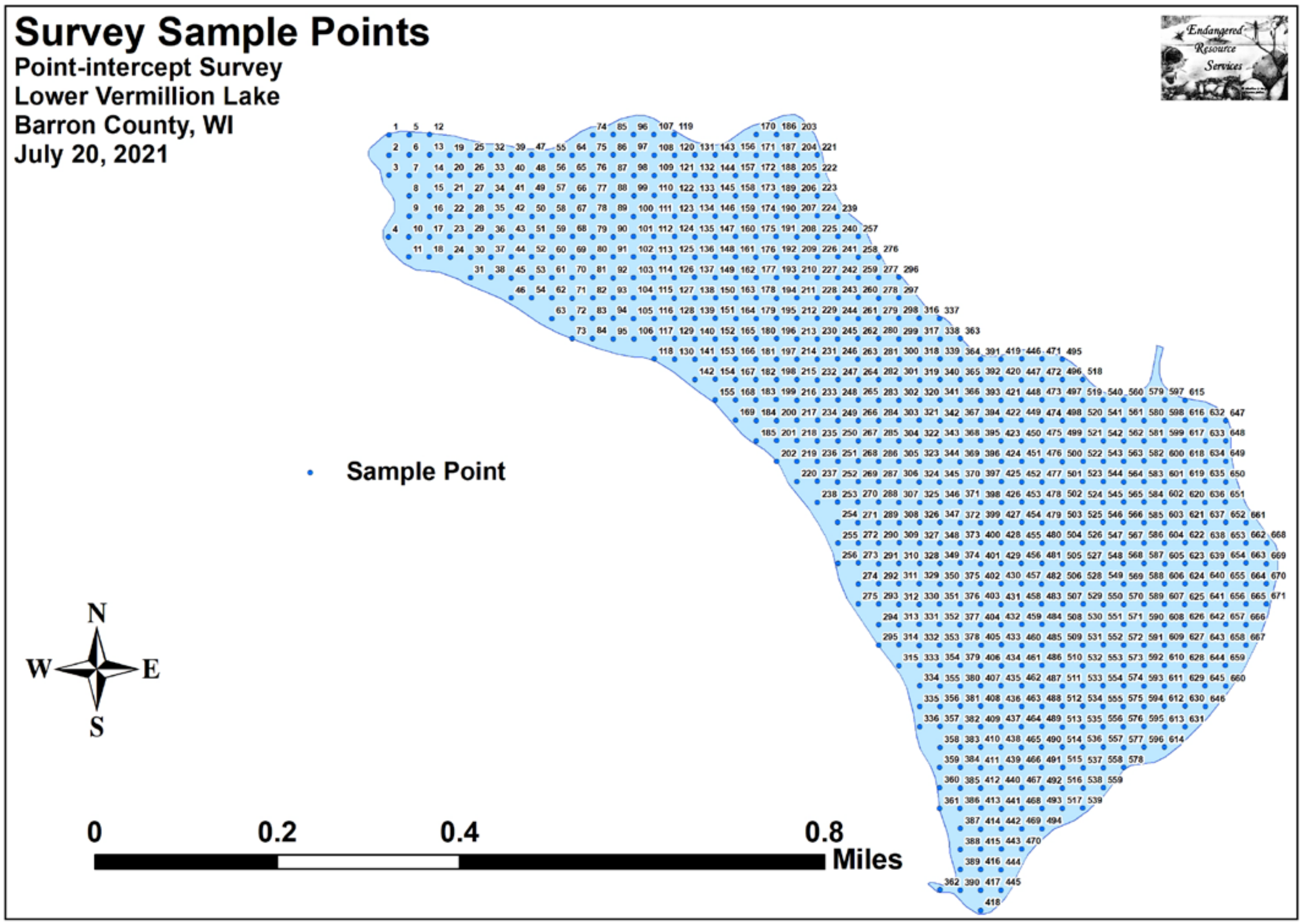
WDNR. [online]. 2010. Curly-leaf pondweed fact sheet. http://dnr.wi.gov/invasives/fact/curlyleaf_pondweed.htm (2010, August).

WDNR. [online]. 2010. Eurasian Water-milfoil fact sheet. http://dnr.wi.gov/invasives/fact/milfoil.htm (2010, August).

WDNR. [online]. 2010. Purple loosestrife fact sheet. http://dnr.wi.gov/invasives/fact/loosestrife.htm (2010, August).

WDNR. [online]. 2010. Reed canary grass fact sheet. http://dnr.wi.gov/invasives/fact/reed_canary.htm (2010, August).

Appendix I: Survey Sample Points Map

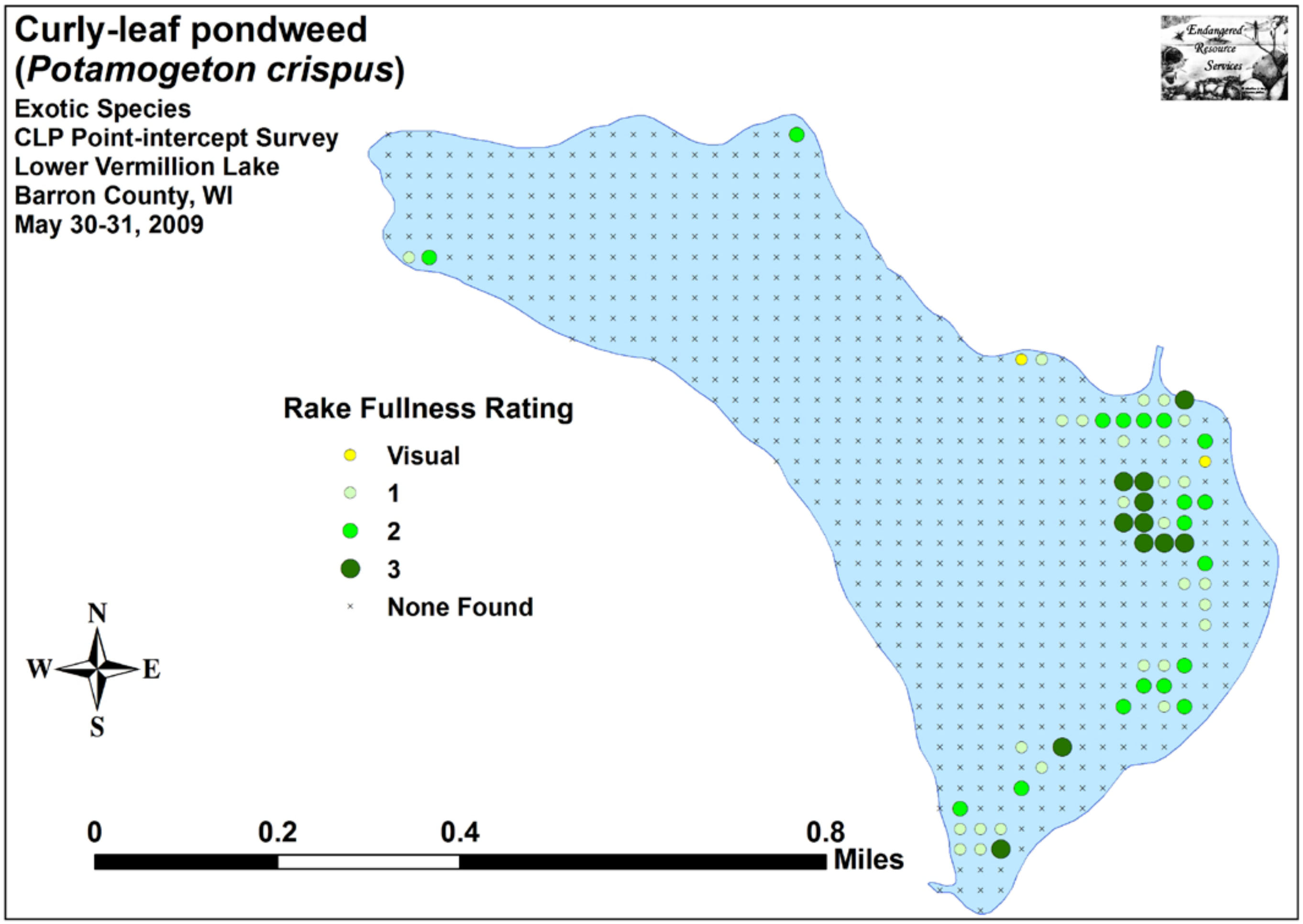

Survey Sample Points
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Sample Point
N
W
E
S
0
0.2
0.4
0.8
Miles

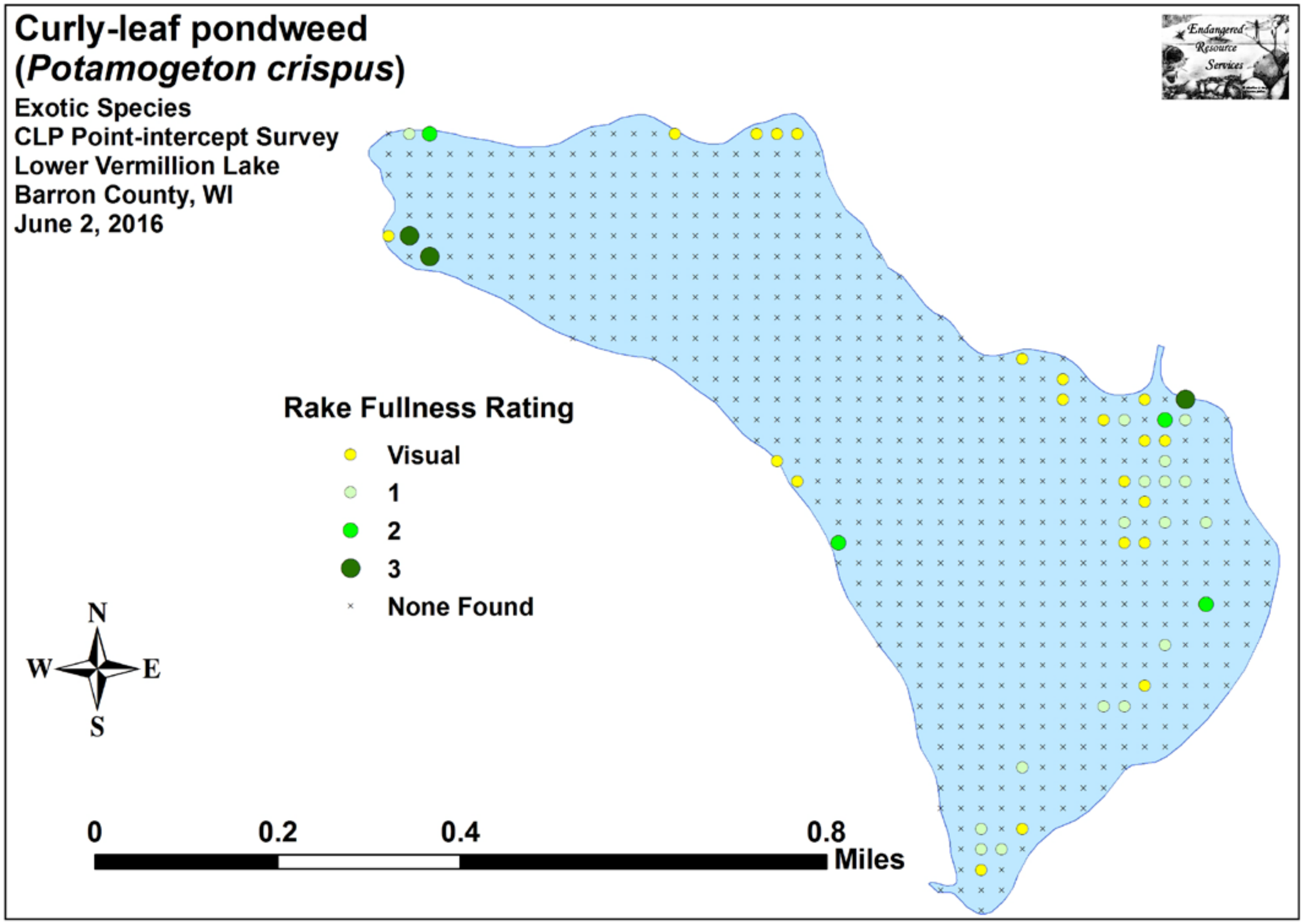
Appendix II: Boat and Vegetative Survey Datasheets

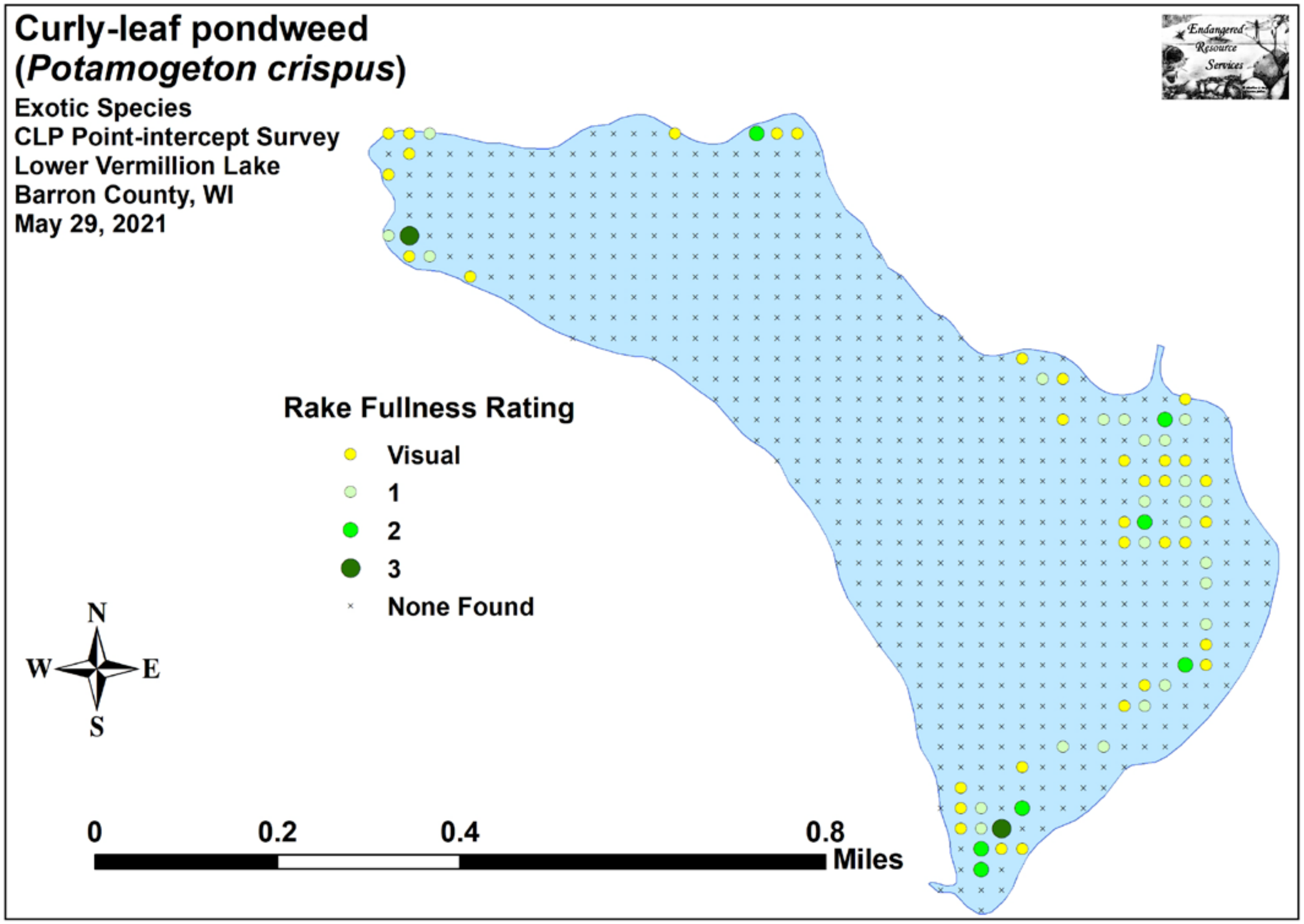
# Boat Survey	
Lake Name	
County	
WBIC	
Date of Survey	
(mm/dd/yy)	
workers	
Nearest Point	**Species seen, habitat information**

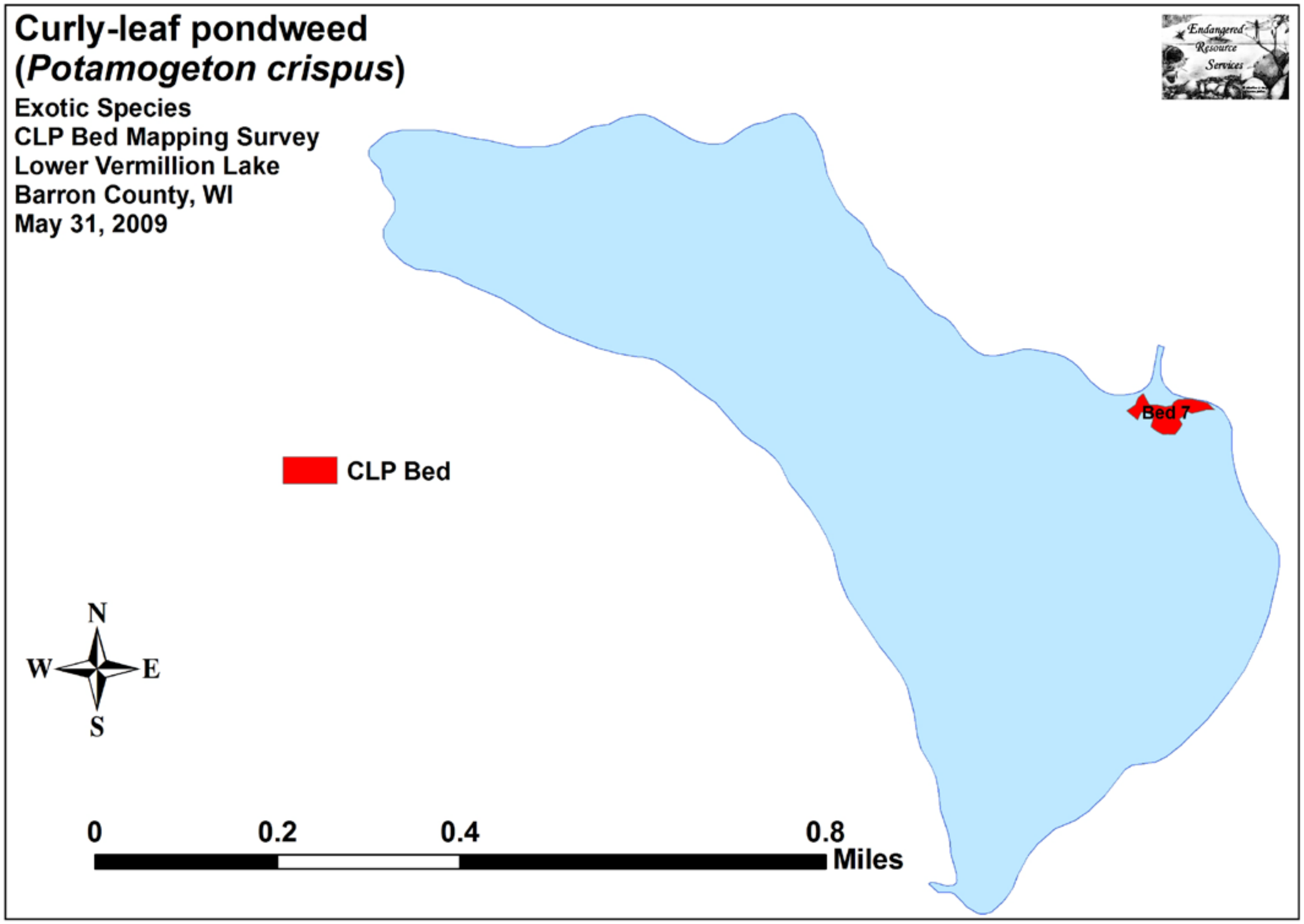
Observers for this lake: names and hours worked by each:																									
Lake:									**WBIC**									**County**						**Date:**	
Site #	**Depth (ft)**	**Muck (M), Sand (S), Rock (R)**	**Rake pole (P) or rake rope (R)**	**Total Rake Fullness**	**EWM**	**CLP**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
1																									
2																									
3																									
4																									
5																									
6																									
7																									
8																									
9																									
10																									
11																									
12																									
13																									
14																									
15																									
16																									
17																									
18																									
19																									
20																									

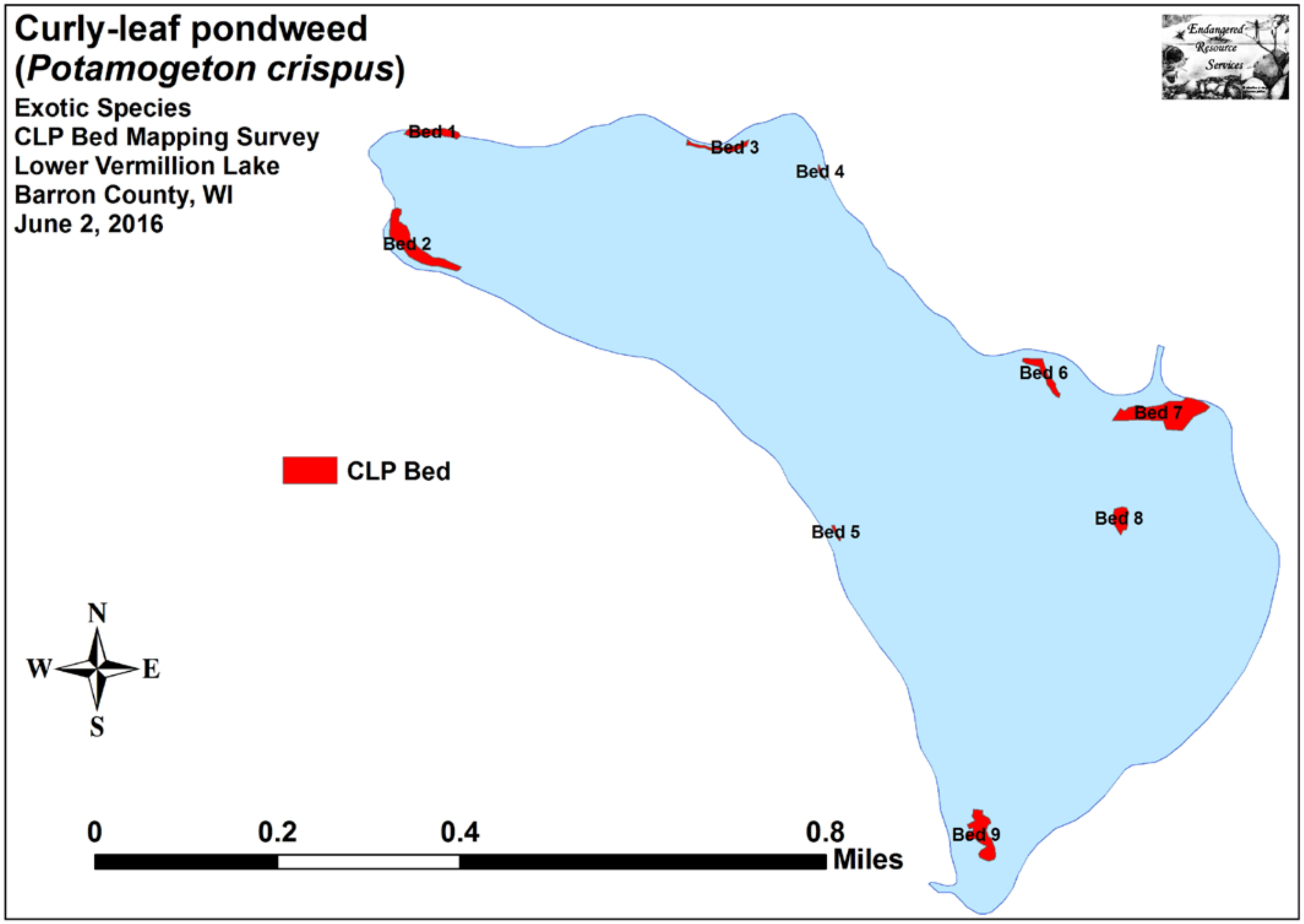
Appendix III: 2009, 2016, and 2021 Early-season CLP Density and Distribution and CLP Bed Maps

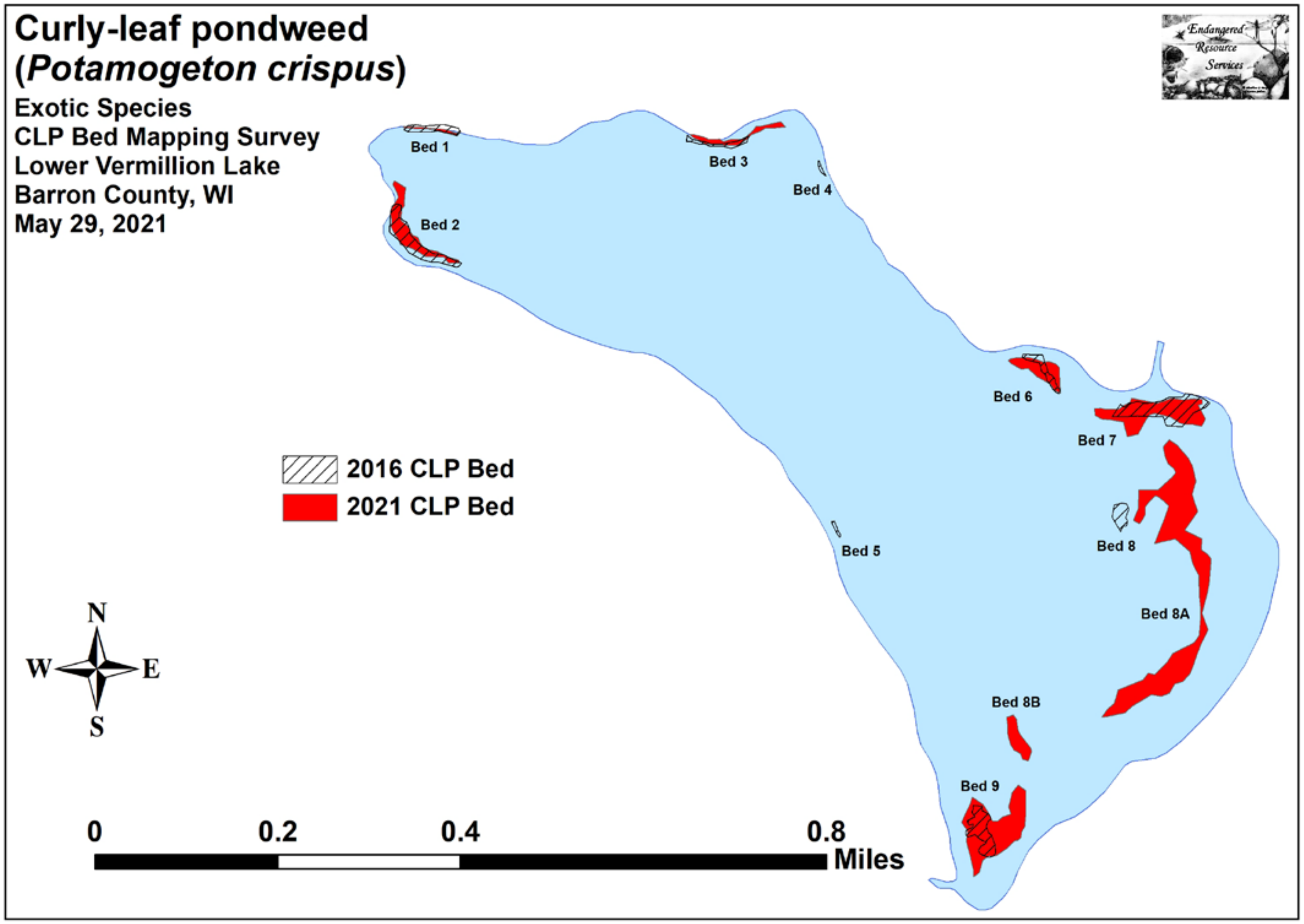

Curly-leaf pondweed
(*Potamogeton crispus*)
Exotic Species
CLP Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
May 30-31, 2009
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles


Curly-leaf pondweed
(Potamogeton crispus)
Exotic Species
CLP Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
June 2, 2016
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

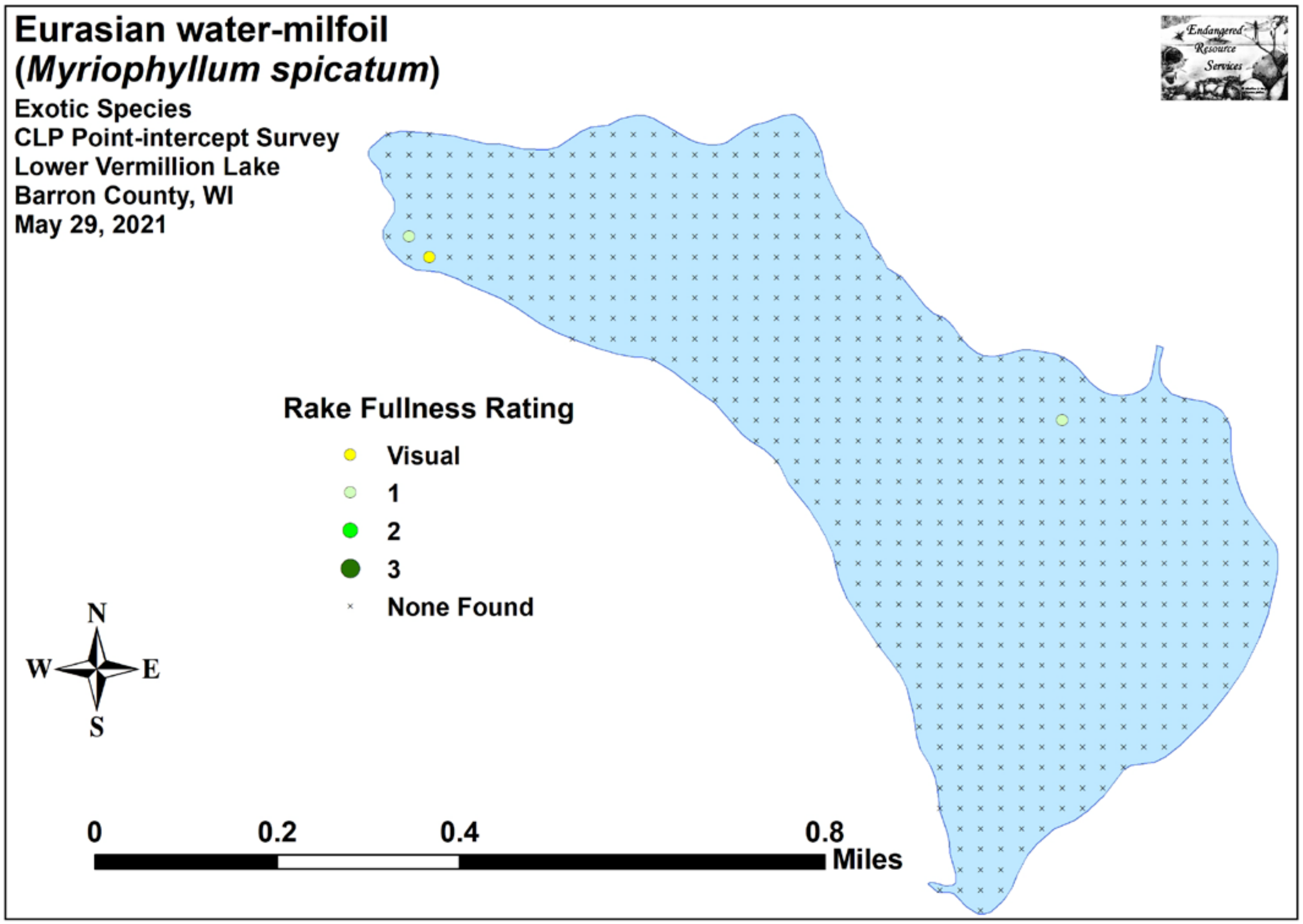

Curly-leaf pondweed
(*Potamogeton crispus*)
Exotic Species
CLP Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
May 29, 2021
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

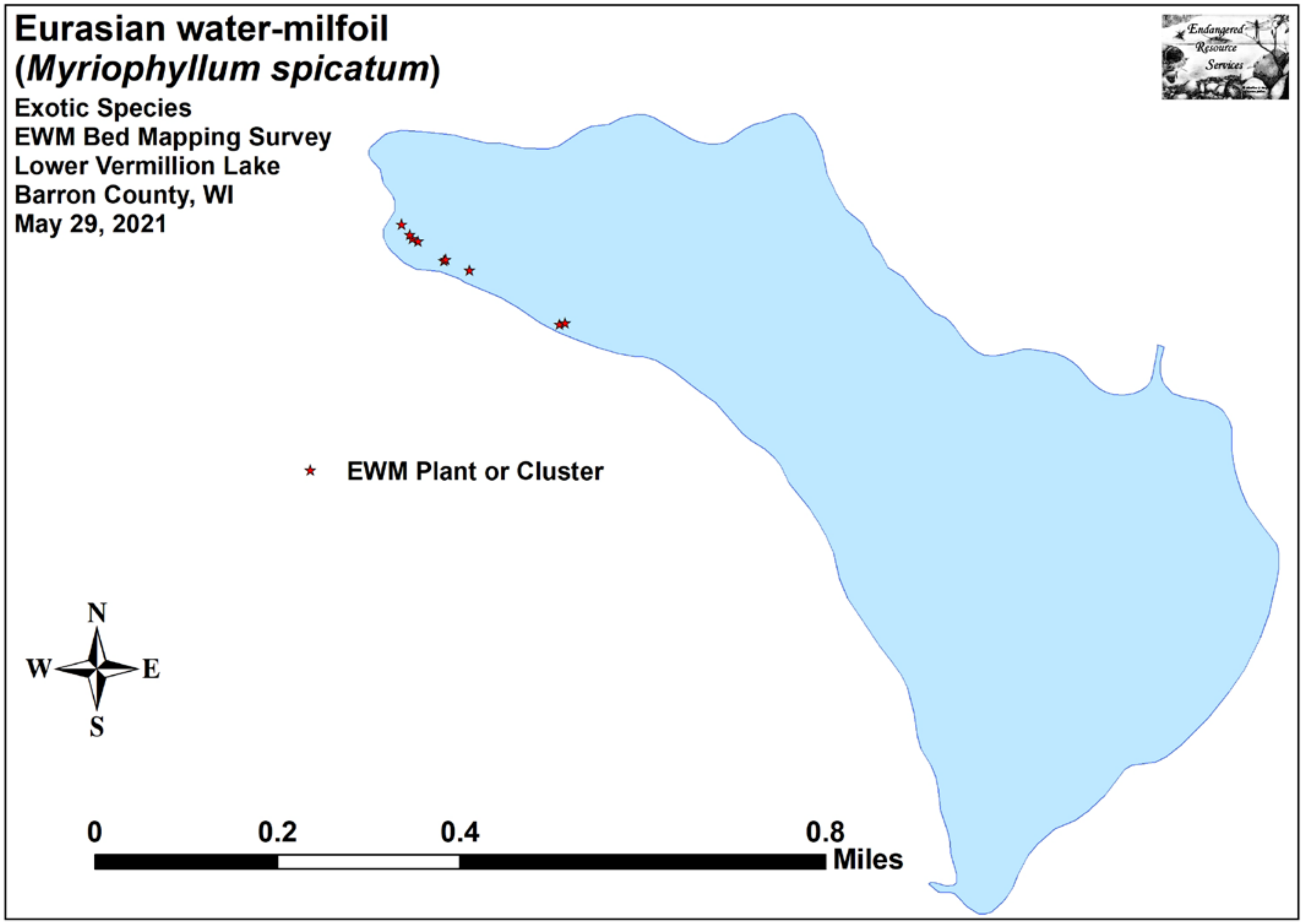

Curly-leaf pondweed
(*Potamogeton crispus*)
Exotic Species
CLP Bed Mapping Survey
Lower Vermillion Lake
Barron County, WI
May 31, 2009
Endangered Resource Services
Bed 7
CLP Bed
N
W
E
S
0
0.2
0.4
0.8
Miles


Curly-leaf pondweed
(*Potamogeton crispus*)
Exotic Species
CLP Bed Mapping Survey
Lower Vermillion Lake
Barron County, WI
June 2, 2016
Endangered Resource Services
Bed 1
Bed 2
Bed 3
Bed 4
Bed 5
Bed 6
Bed 7
Bed 8
Bed 9
CLP Bed
N
W
E
S
0
0.2
0.4
0.8
Miles

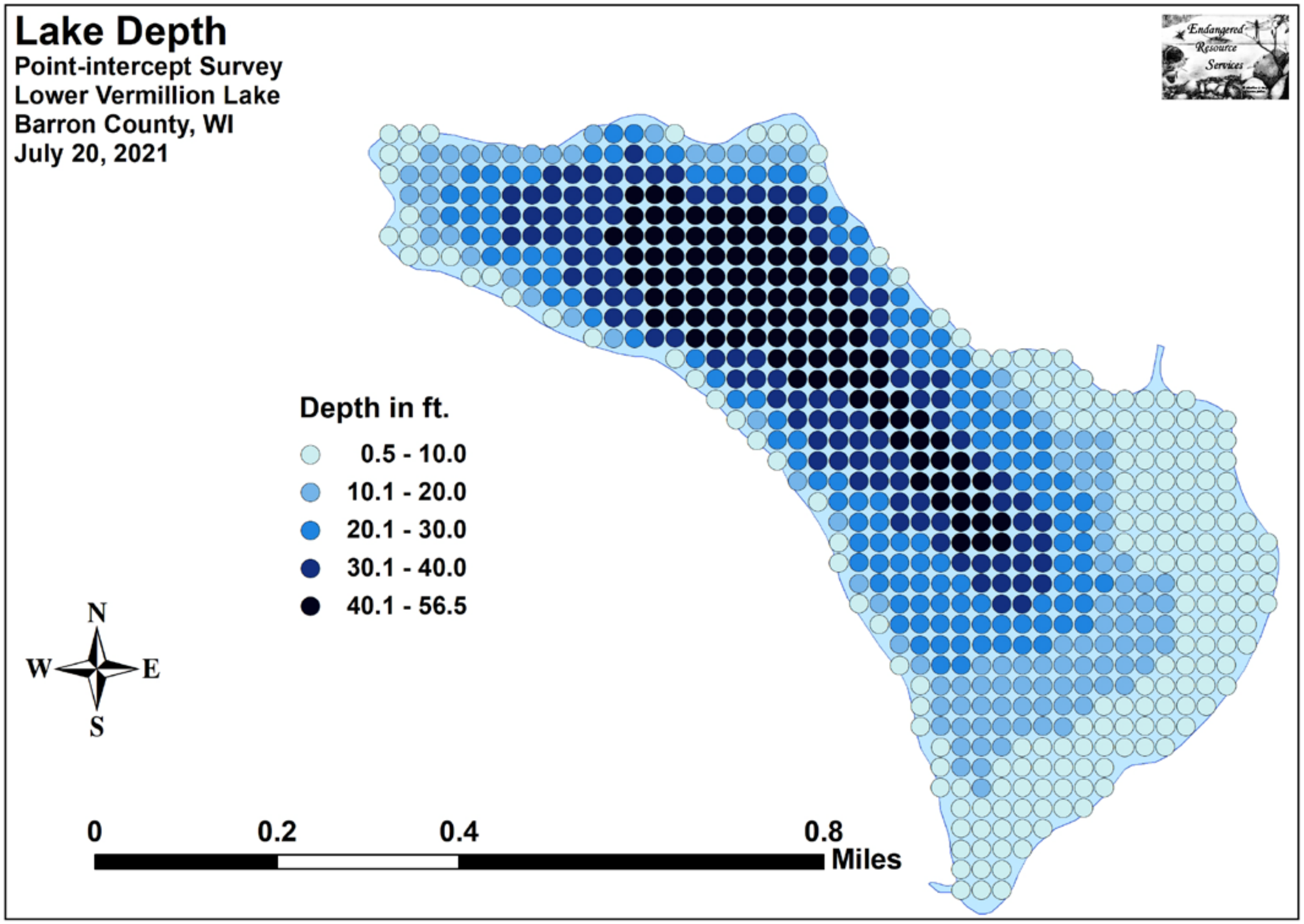

Curly-leaf pondweed
(Potamogeton crispus)
Exotic Species
CLP Bed Mapping Survey
Lower Vermillion Lake
Barron County, WI
May 29, 2021
Endangered Resource Services
Bed 1
Bed 2
Bed 3
Bed 4
Bed 5
Bed 6
Bed 7
Bed 8
Bed 8A
Bed 8B
Bed 9
2016 CLP Bed
2021 CLP Bed
N
S
E
W
0
0.2
0.4
0.8
Miles

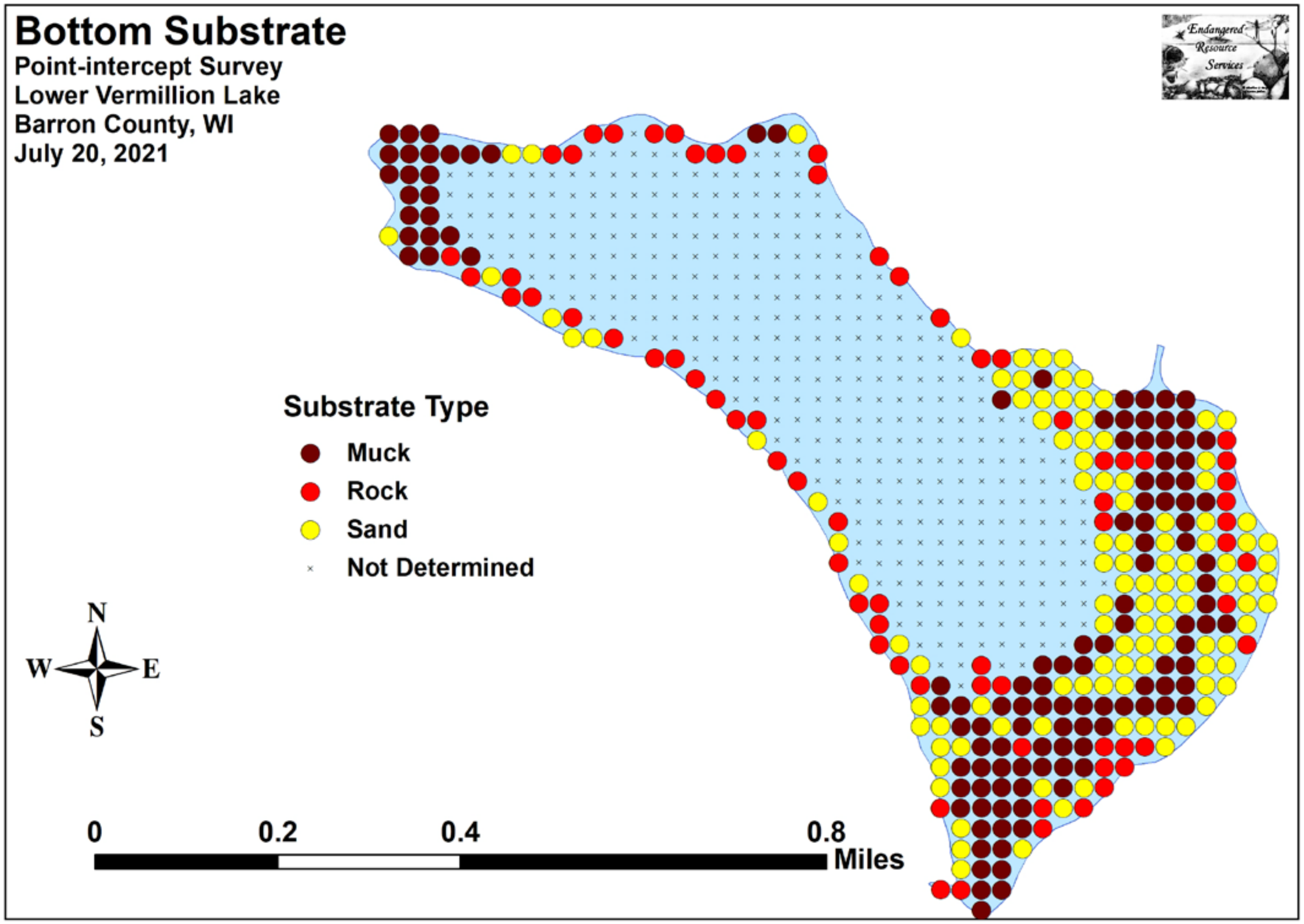
Appendix IV: 2021 Early-season EWM Density and Distribution and EWM Bed Maps


Eurasian water-milfoil
(*Myriophyllum spicatum*)
Exotic Species
CLP Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
May 29, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

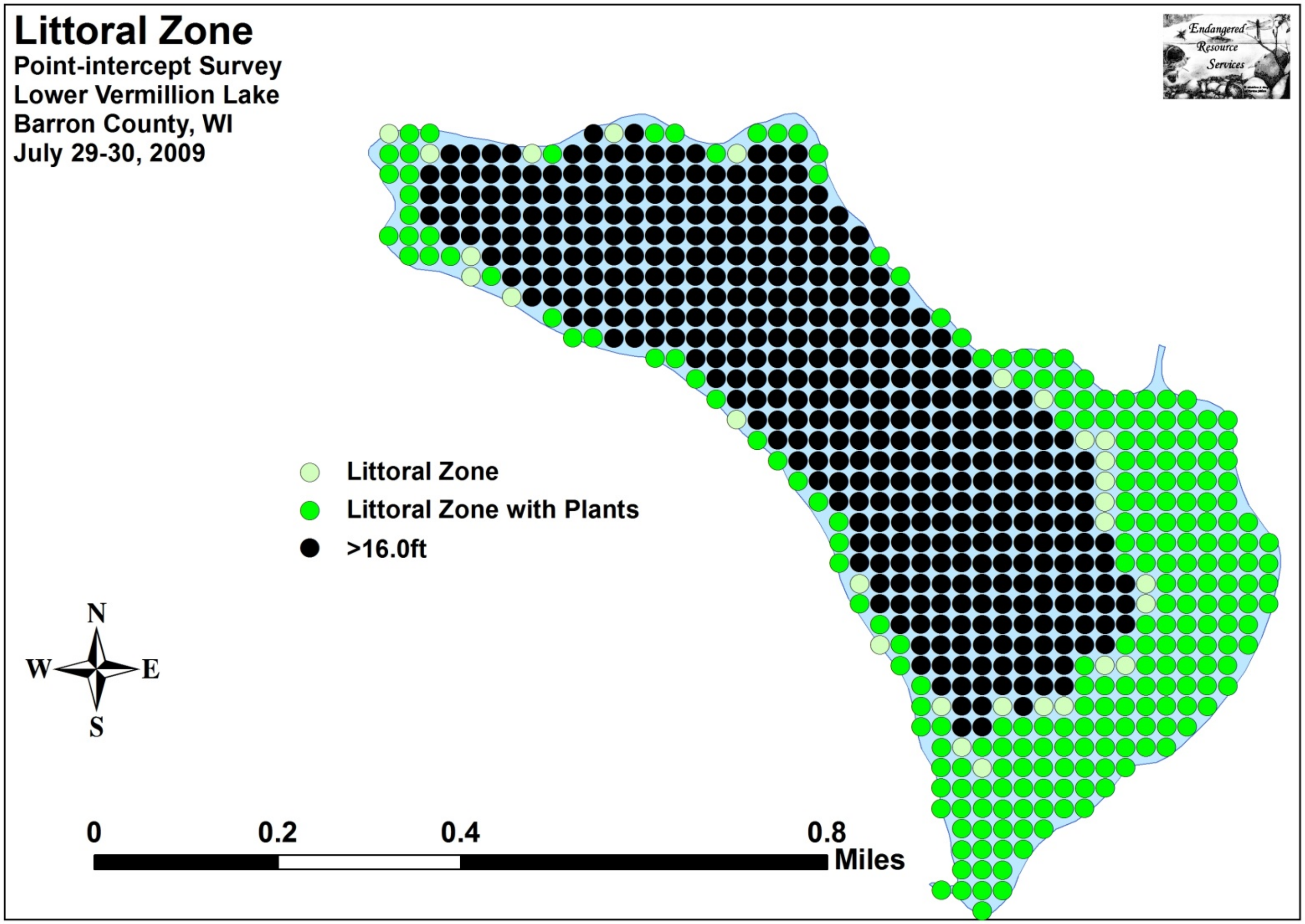

Eurasian water-milfoil
(*Myriophyllum spicatum*)
Exotic Species
EWM Bed Mapping Survey
Lower Vermillion Lake
Barron County, WI
May 29, 2021
Endangered Resource Services
EWM Plant or Cluster
N
W
E
S
0
0.2
0.4
0.8
Miles

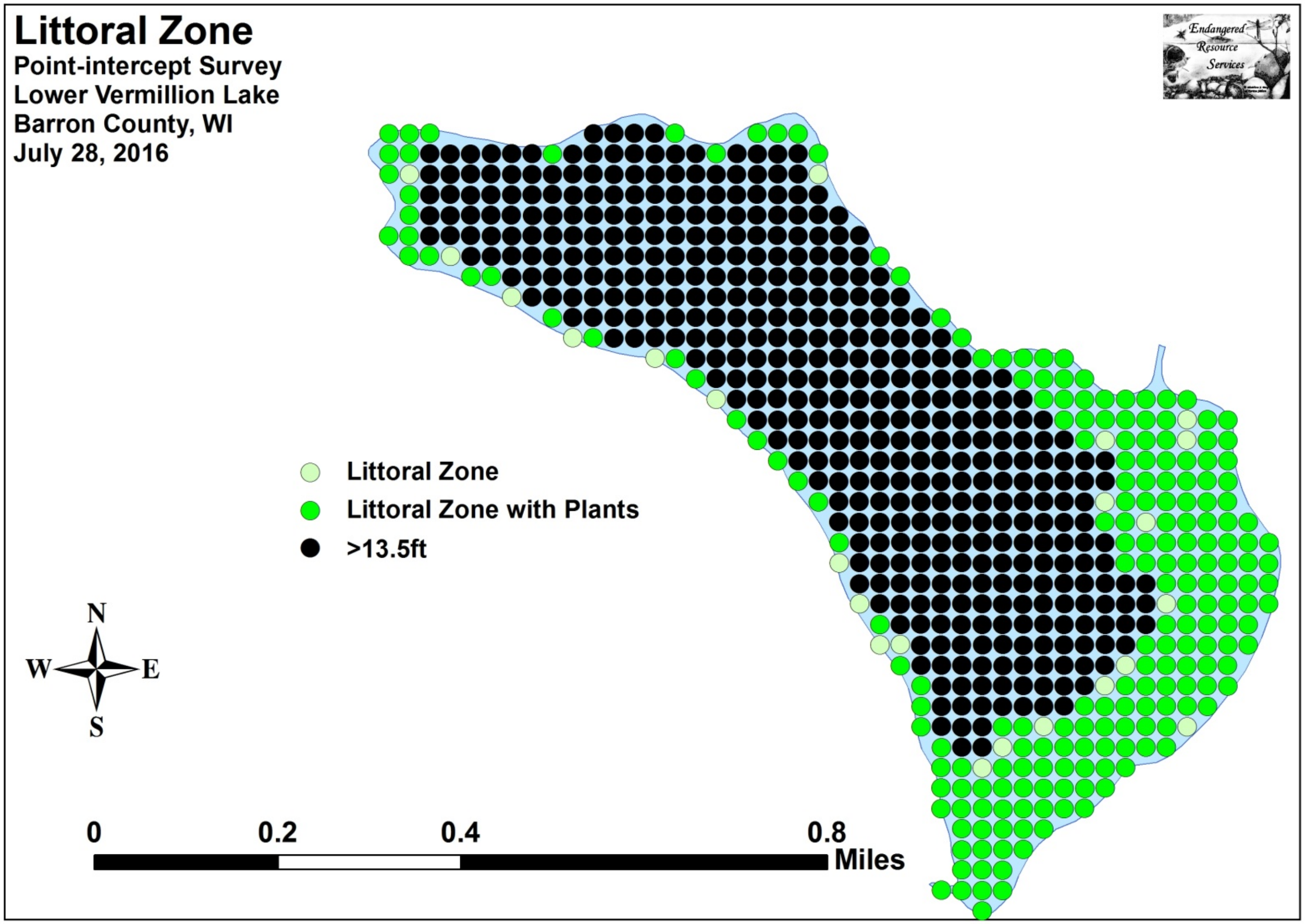
Appendix V: Habitat Variable Maps

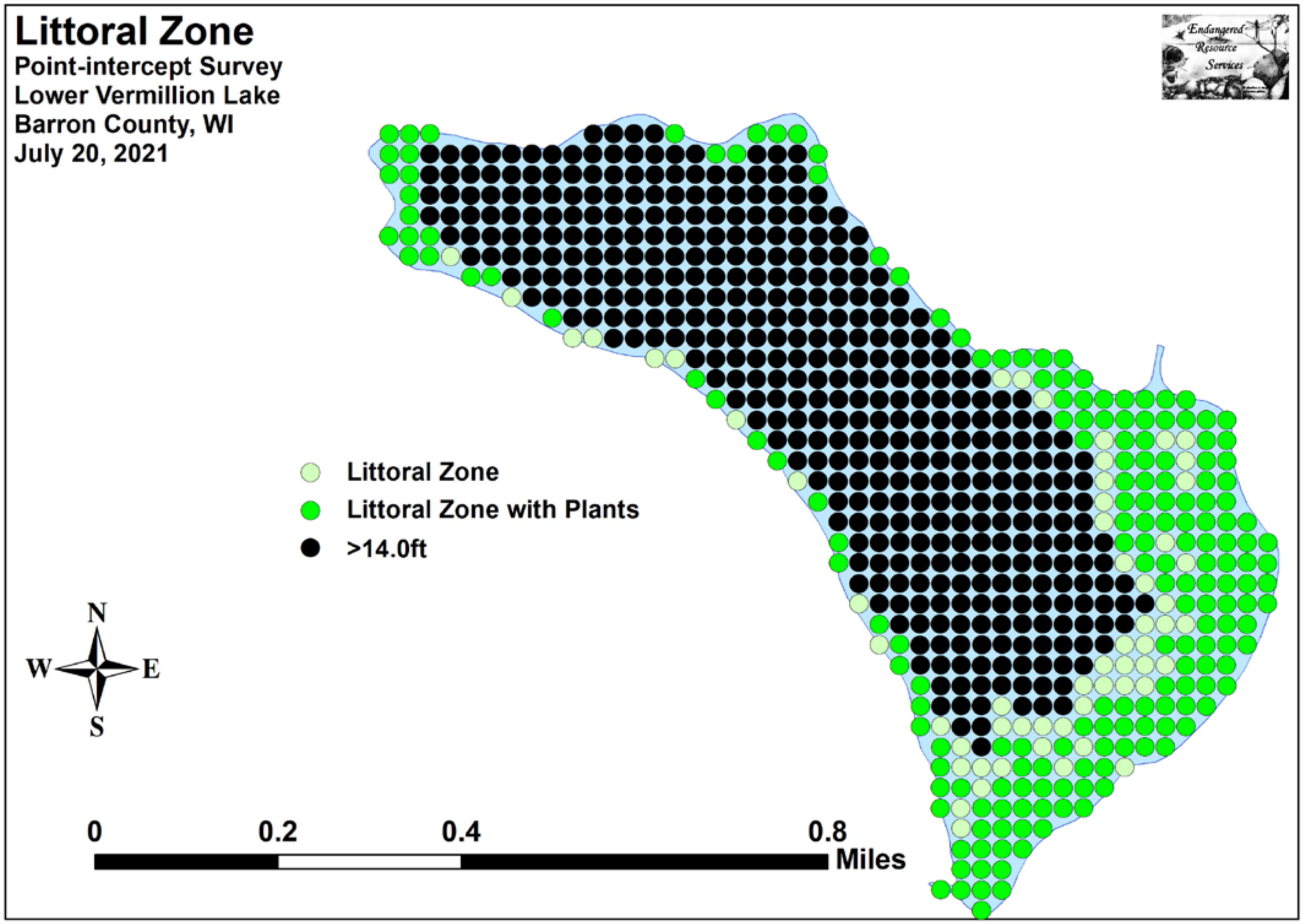

Lake Depth
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Depth in ft.
0.5 - 10.0
10.1 - 20.0
20.1 - 30.0
30.1 - 40.0
40.1 - 56.5
N
W
E
S
0
0.2
0.4
0.8
Miles

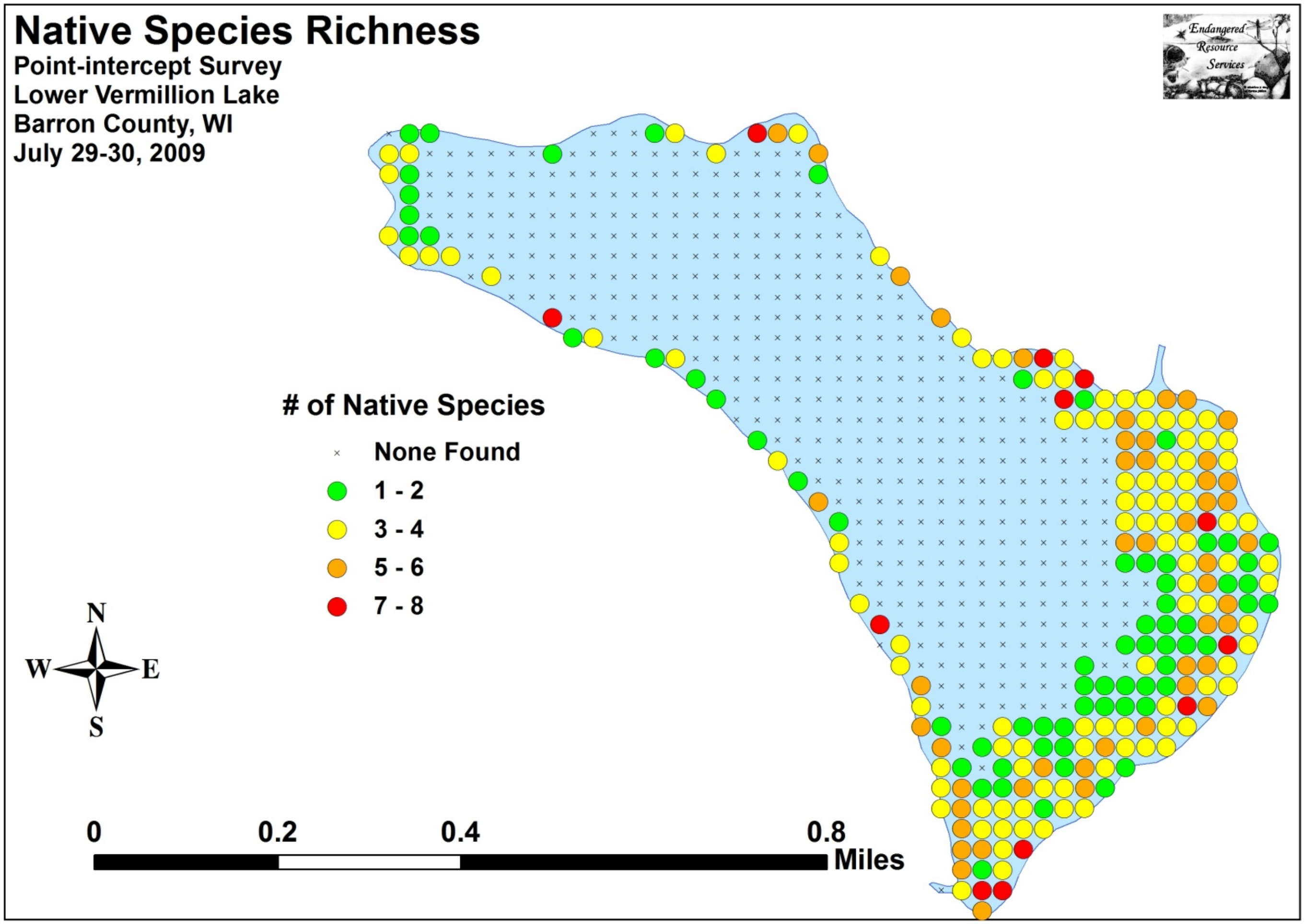

Bottom Substrate
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Substrate Type
Muck
Rock
Sand
Not Determined
N
W
E
S
0
0.2
0.4
0.8
Miles

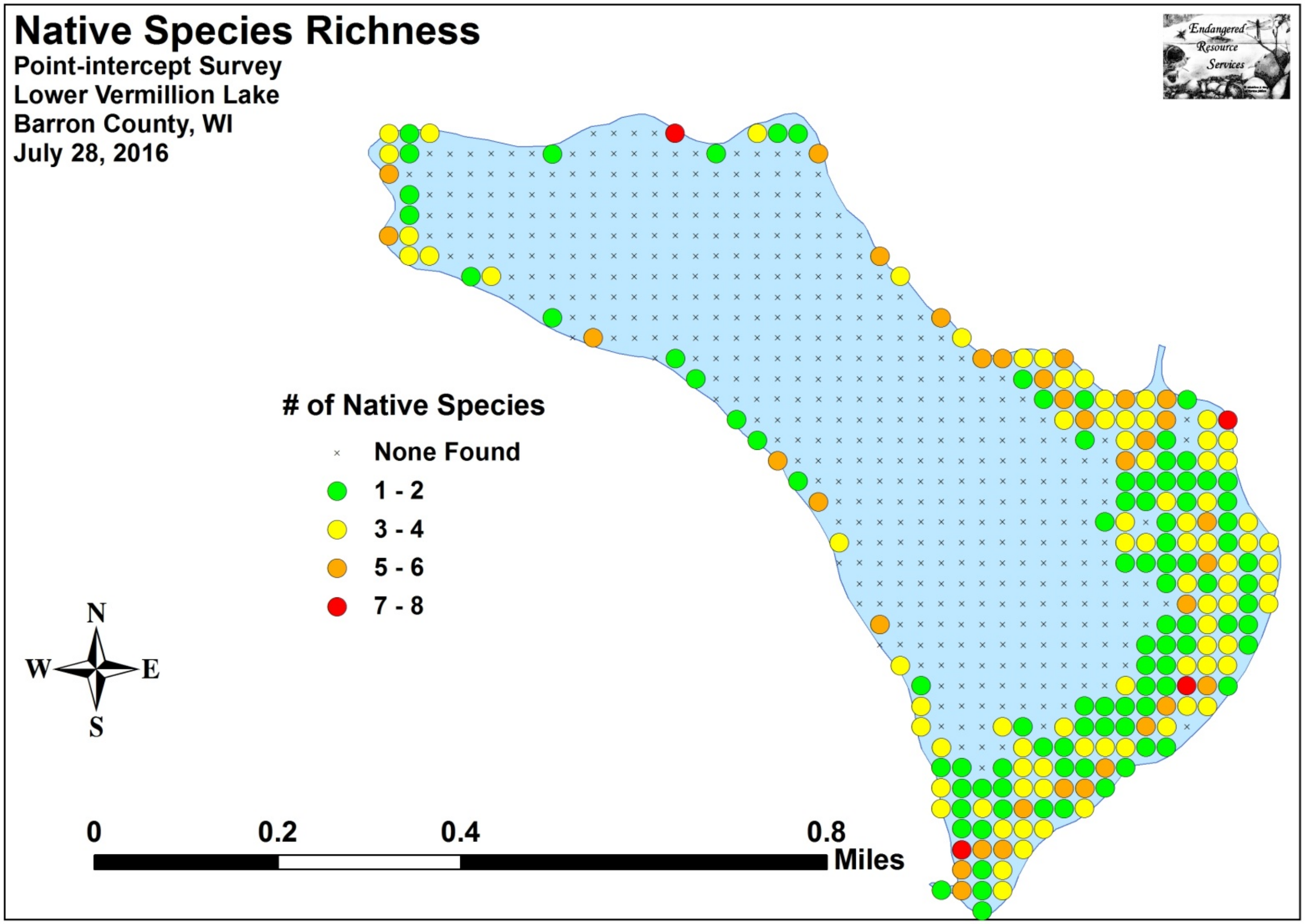
Appendix VI: 2009, 2016, and 2021 Littoral Zone, Native Species Richness, and Total Rake Fullness Maps

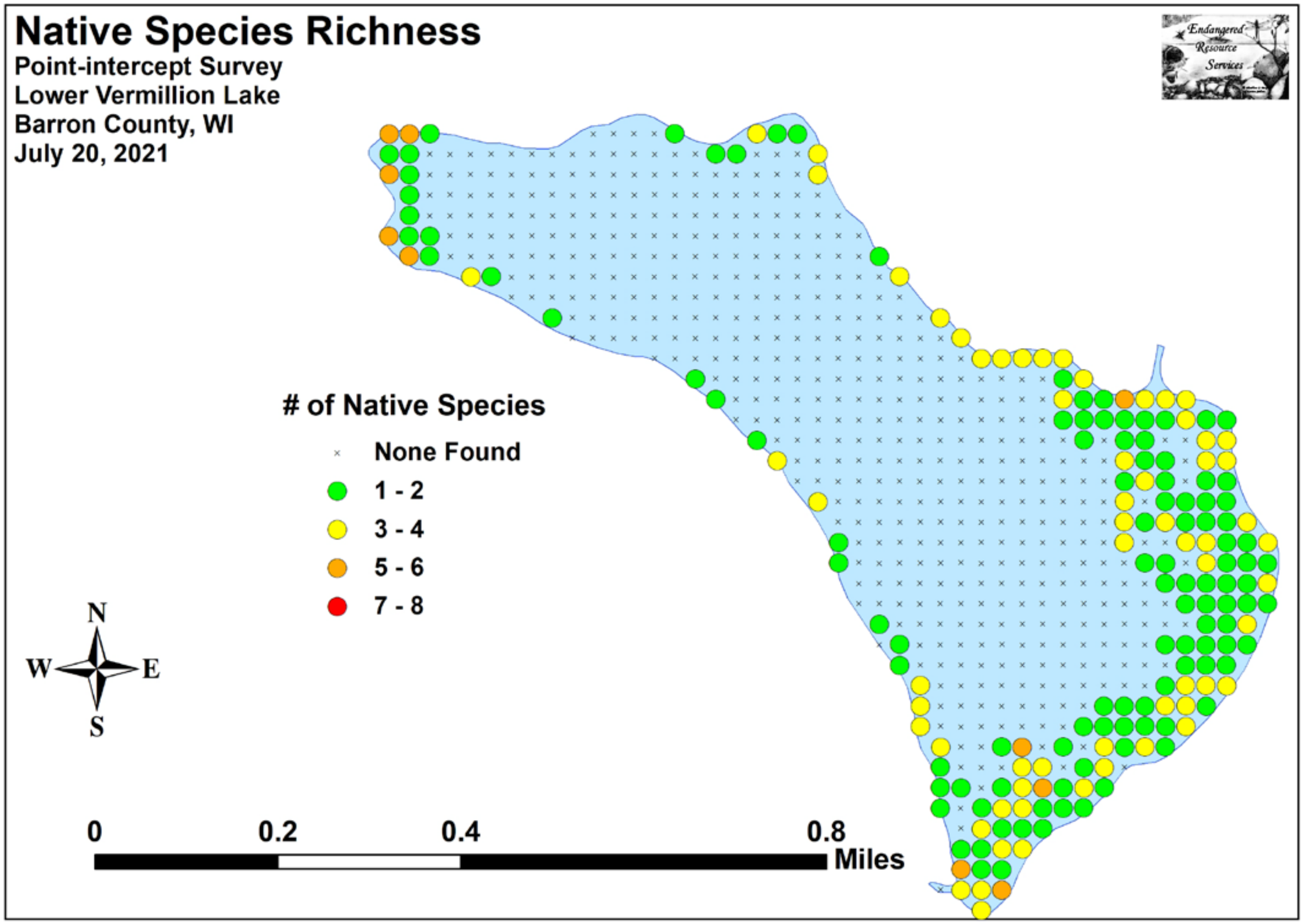

Littoral Zone
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 29-30, 2009
Endangered Resource Services
Littoral Zone
Littoral Zone with Plants
>16.0ft
N
W
E
S
0
0.2
0.4
0.8
Miles

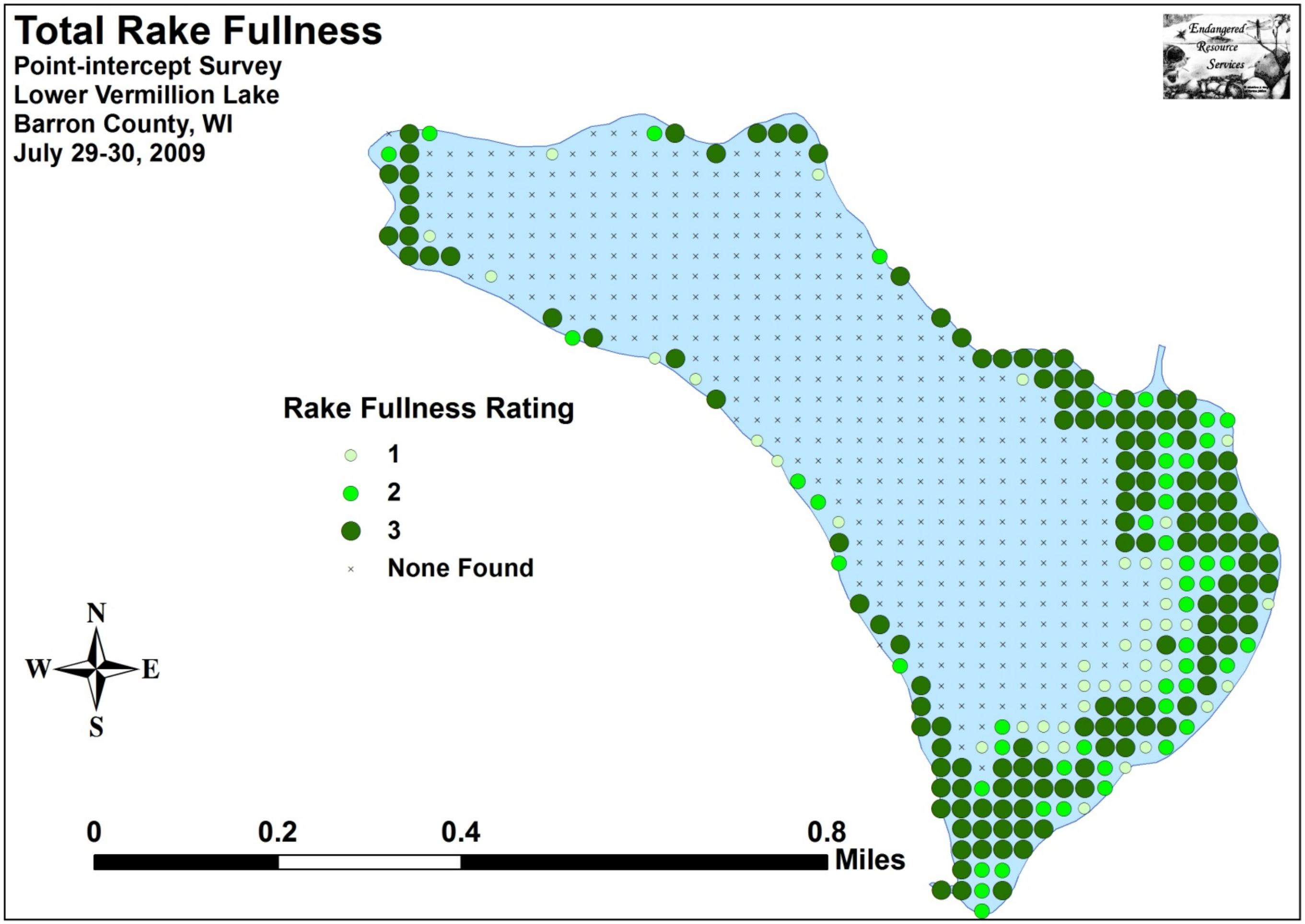

Littoral Zone
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 28, 2016
Endangered Resource Services
Littoral Zone
Littoral Zone with Plants
>13.5ft
N
W
E
S
0
0.2
0.4
0.8
Miles


Littoral Zone
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Littoral Zone
Littoral Zone with Plants
>14.0ft
N
W
E
S
0
0.2
0.4
0.8
Miles

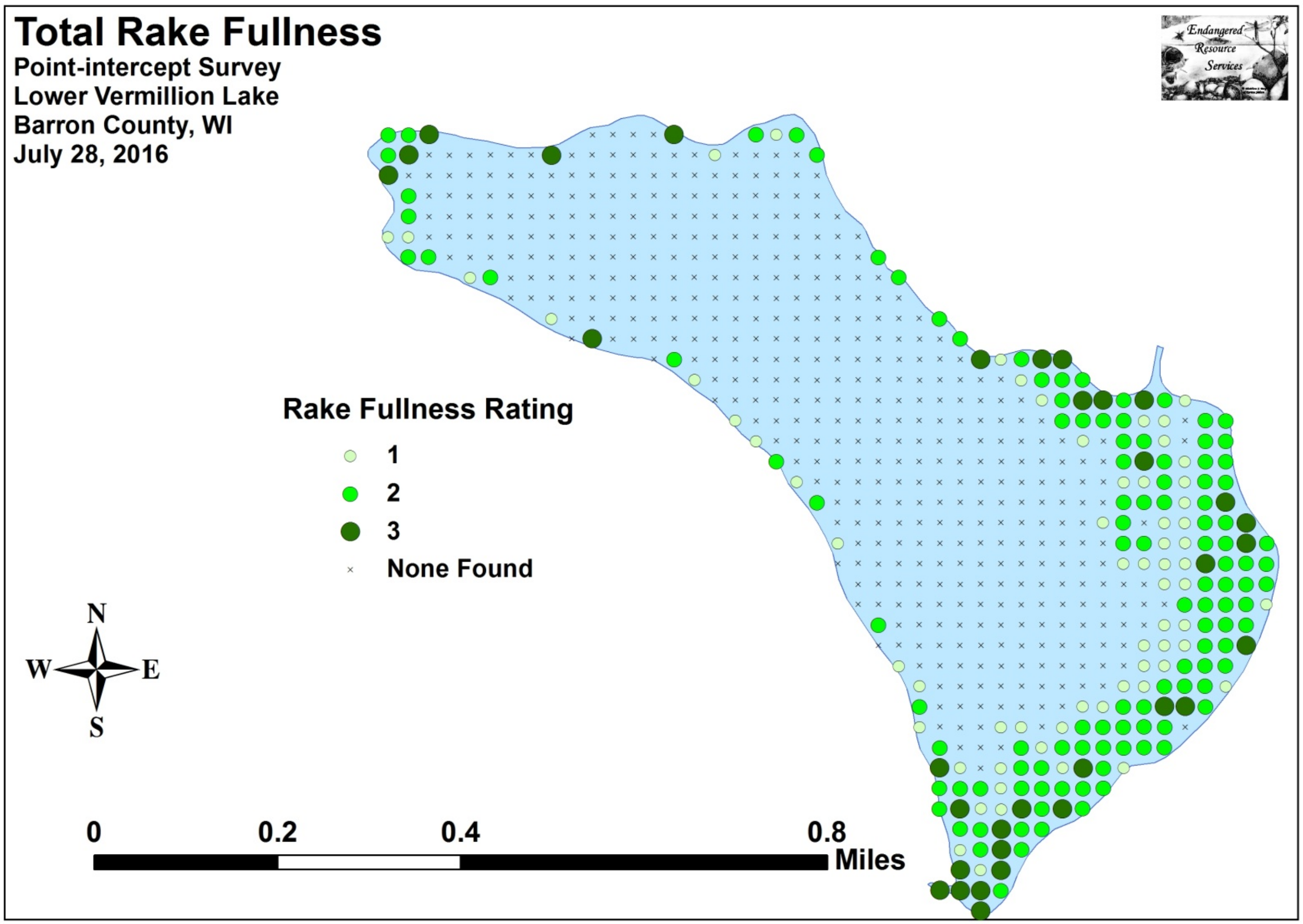

Native Species Richness
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 29-30, 2009
Endangered Resource Services
# of Native Species
None Found
1 - 2
3 - 4
5 - 6
7 - 8
N
W
E
S
0
0.2
0.4
0.8
Miles

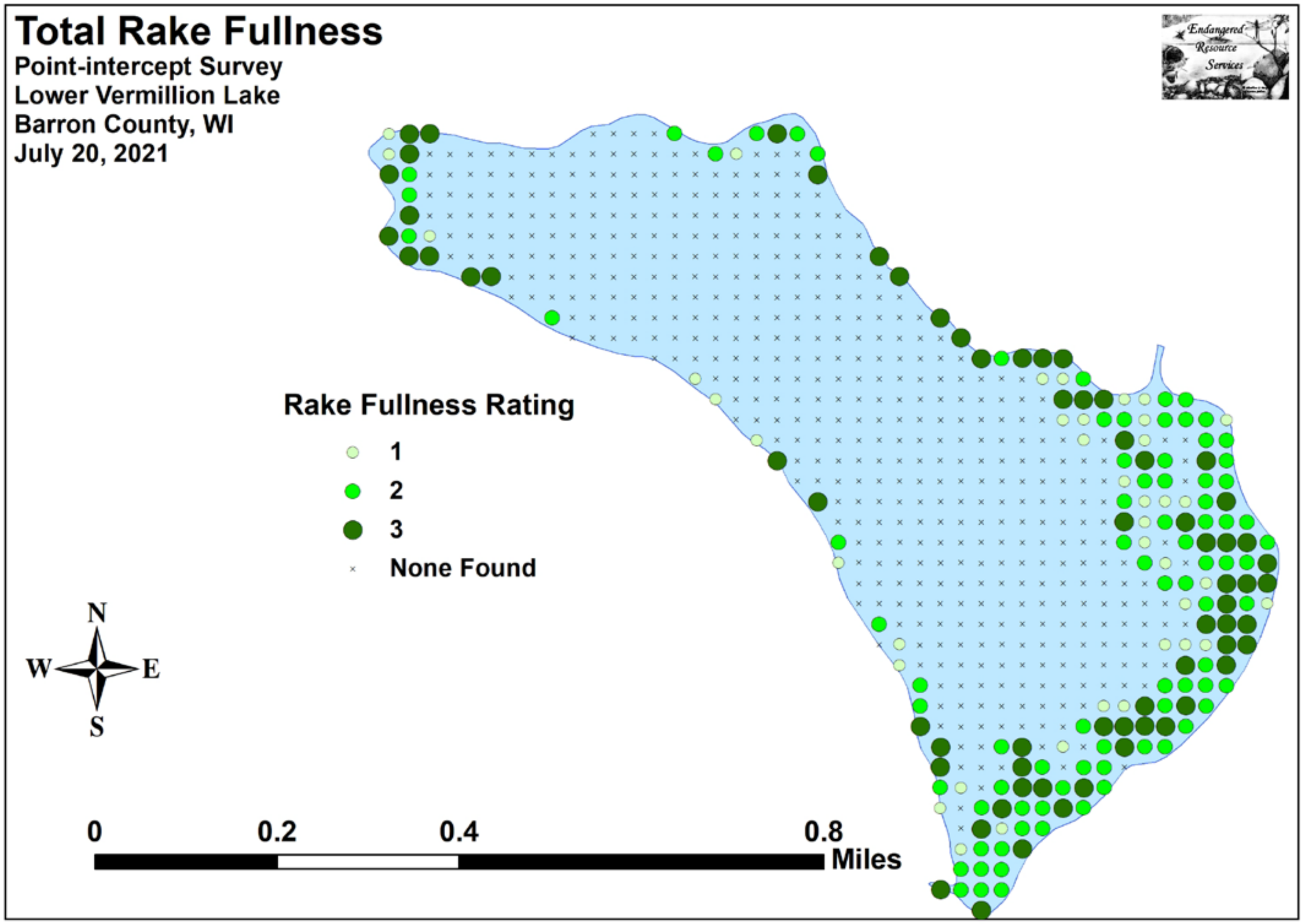

Native Species Richness
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 28, 2016
Endangered Resource Services
# of Native Species
None Found
1 - 2
3 - 4
5 - 6
7 - 8
N
W
E
S
0
0.2
0.4
0.8
Miles


Native Species Richness
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
# of Native Species
None Found
1 - 2
3 - 4
5 - 6
7 - 8
N
W
E
S
0
0.2
0.4
0.8
Miles

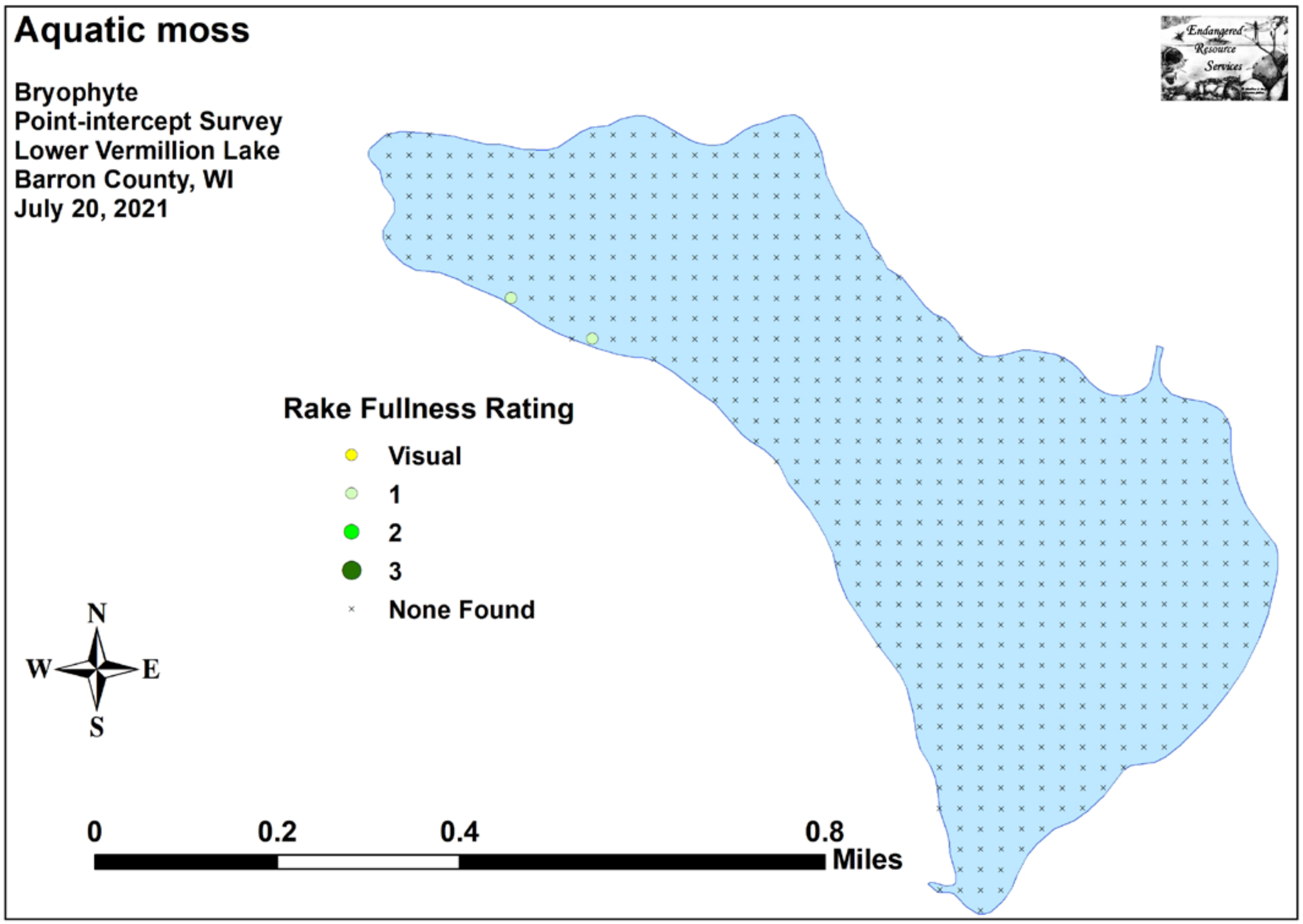


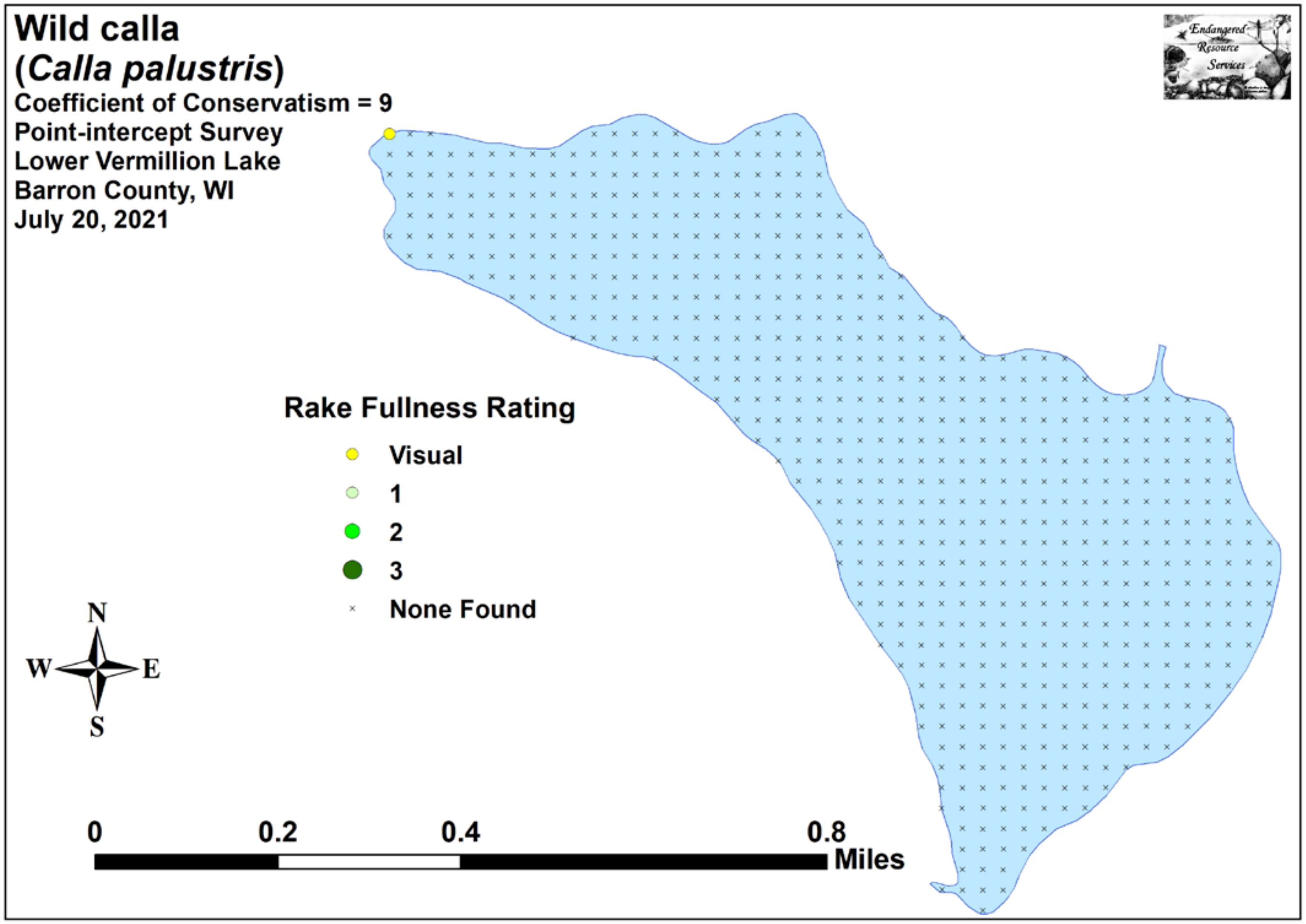
Total Rake Fullness
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 29-30, 2009
Endangered Resource Services
Rake Fullness Rating
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

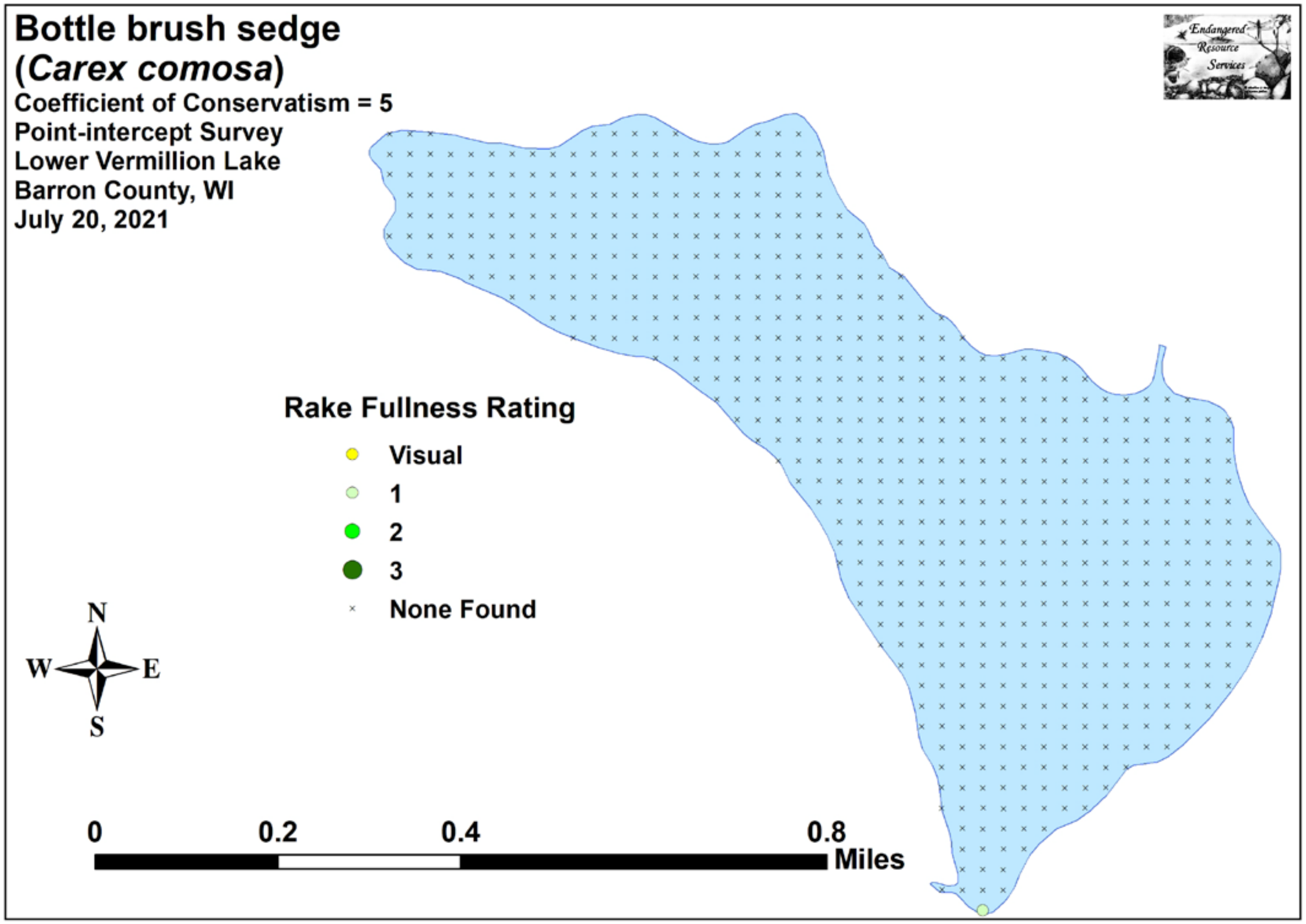

Total Rake Fullness
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 28, 2016
Endangered Resource Services
Rake Fullness Rating
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

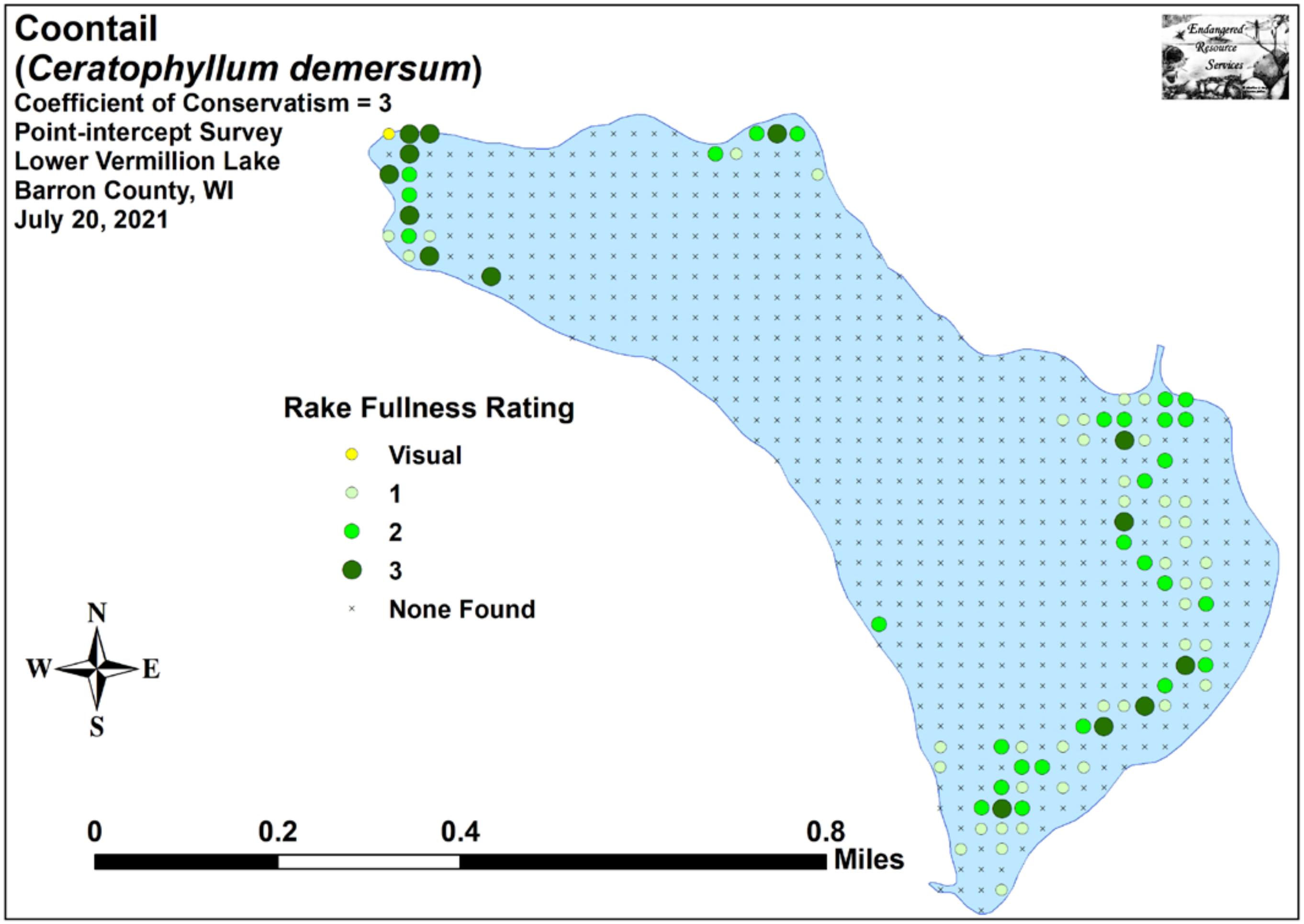

Total Rake Fullness
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

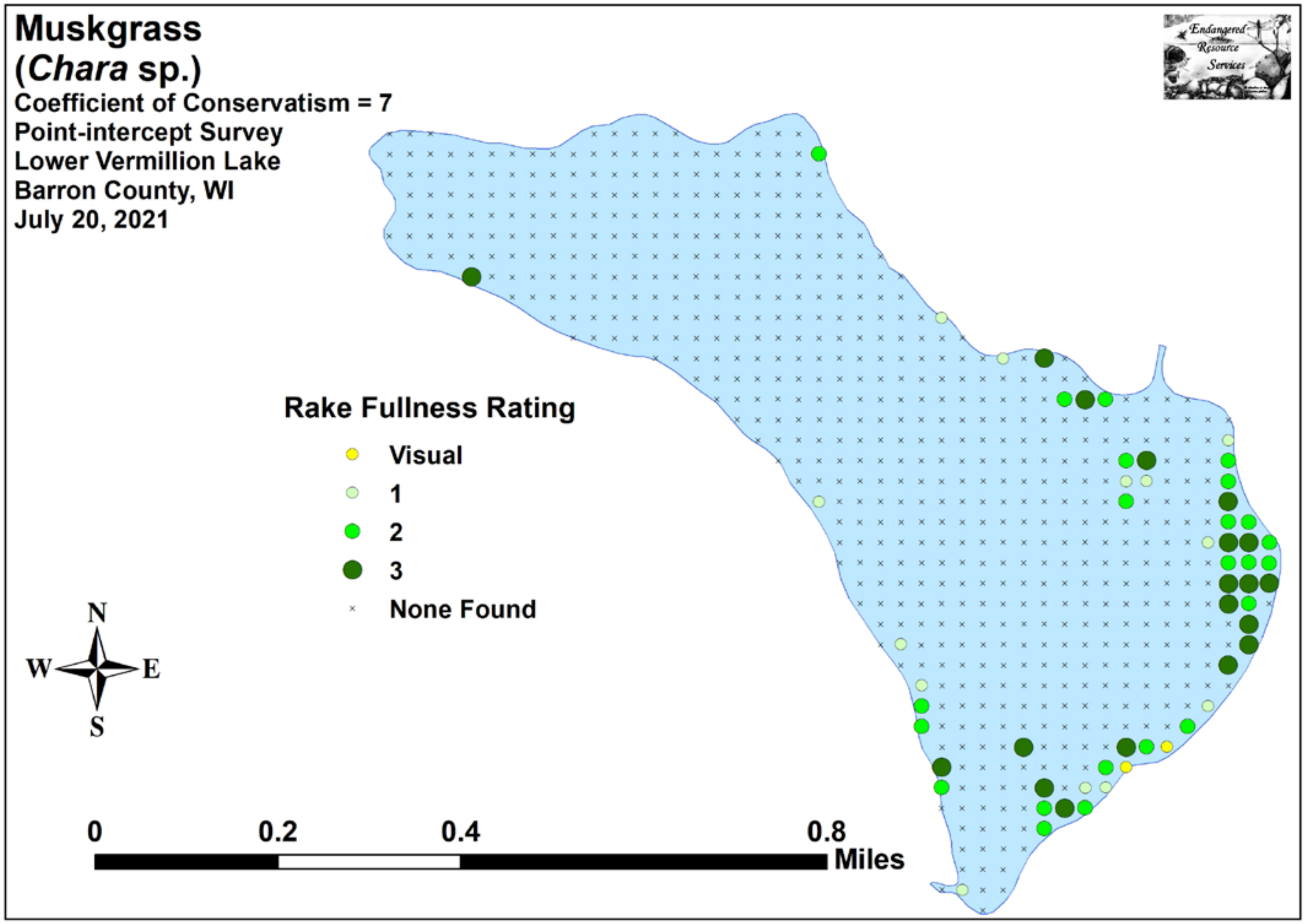
Appendix VII: July 2021 Native Species Density and Distribution Maps

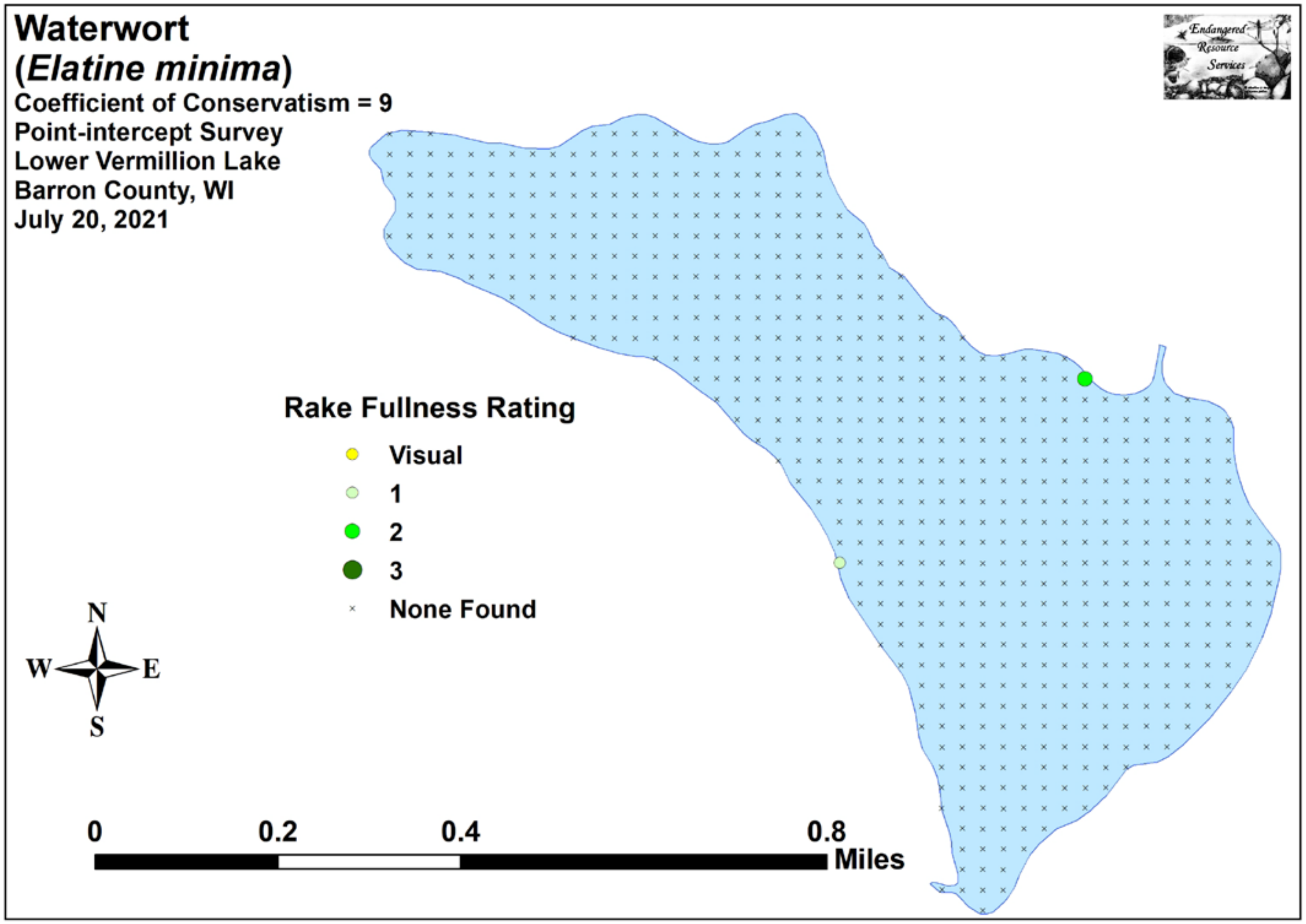

Aquatic moss
Bryophyte
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

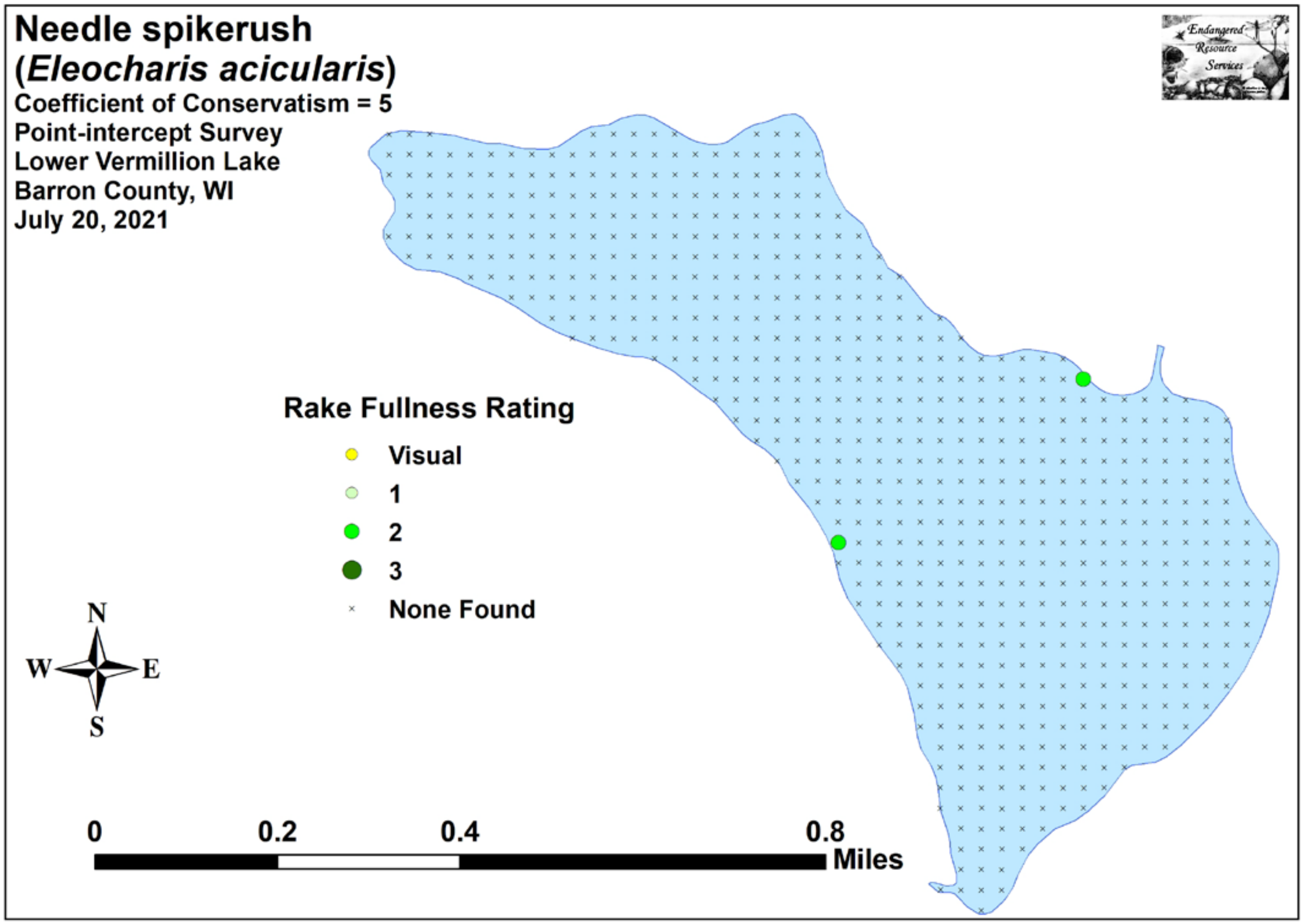

Wild calla
(Calla palustris)
Coefficient of Conservatism = 9
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

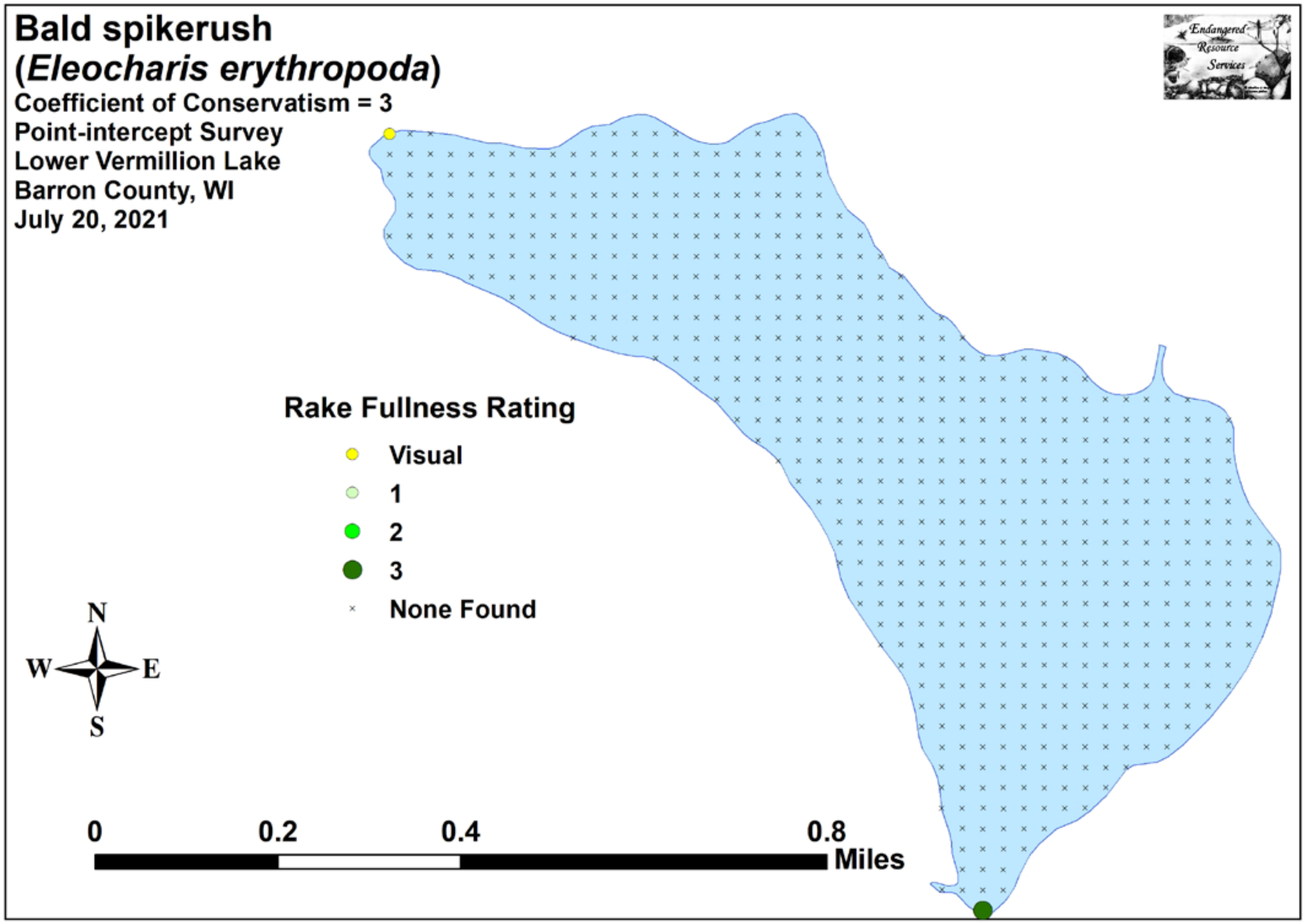

Bottle brush sedge
(*Carex comosa*)
Coefficient of Conservatism = 5
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles


Coontail
(*Ceratophyllum demersum*)
Coefficient of Conservatism = 3
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

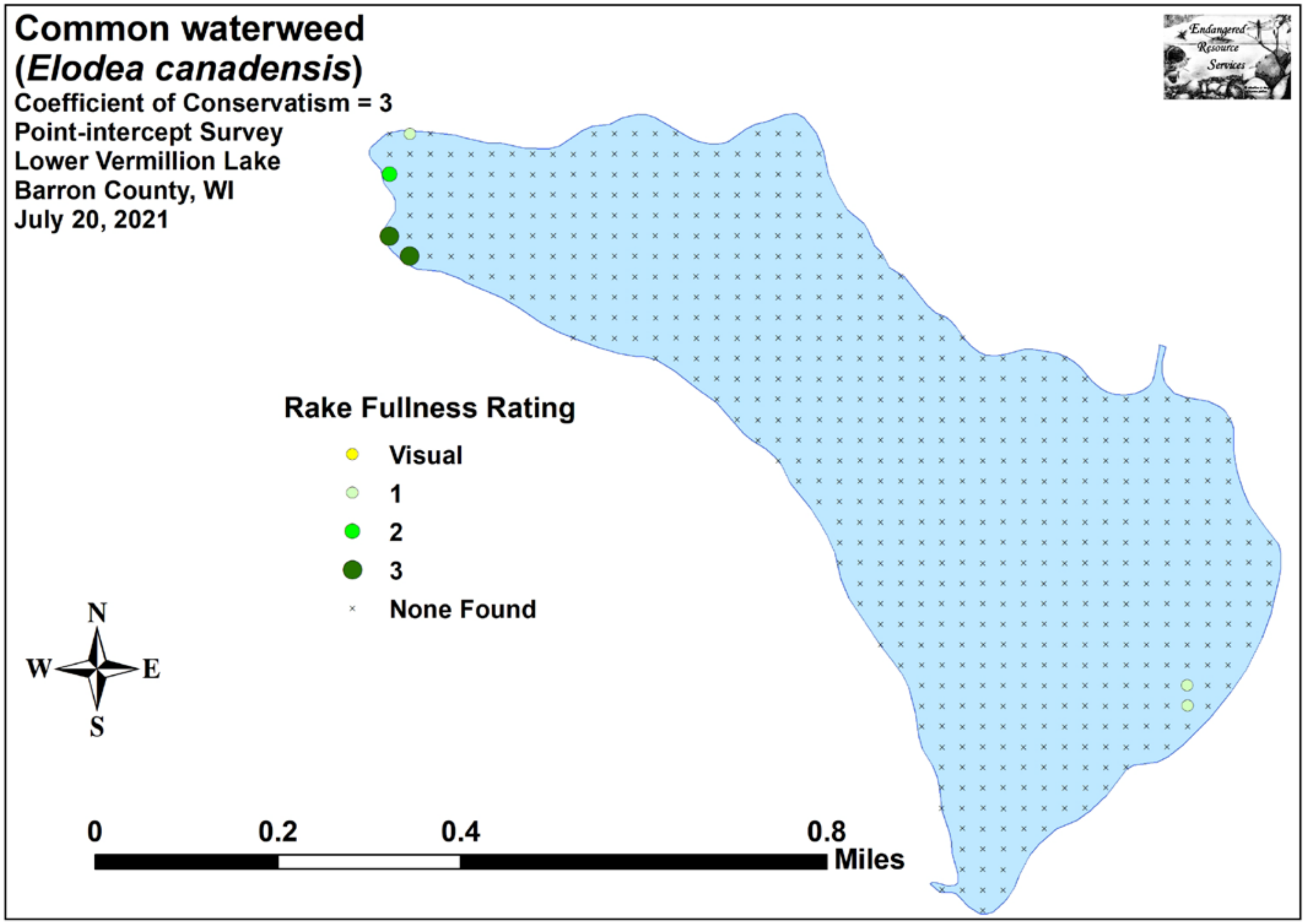

Muskgrass
(Chara sp.)
Coefficient of Conservatism = 7
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles
Endangered Resource Services


Waterwort
(Elatine minima)
Coefficient of Conservatism = 9
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

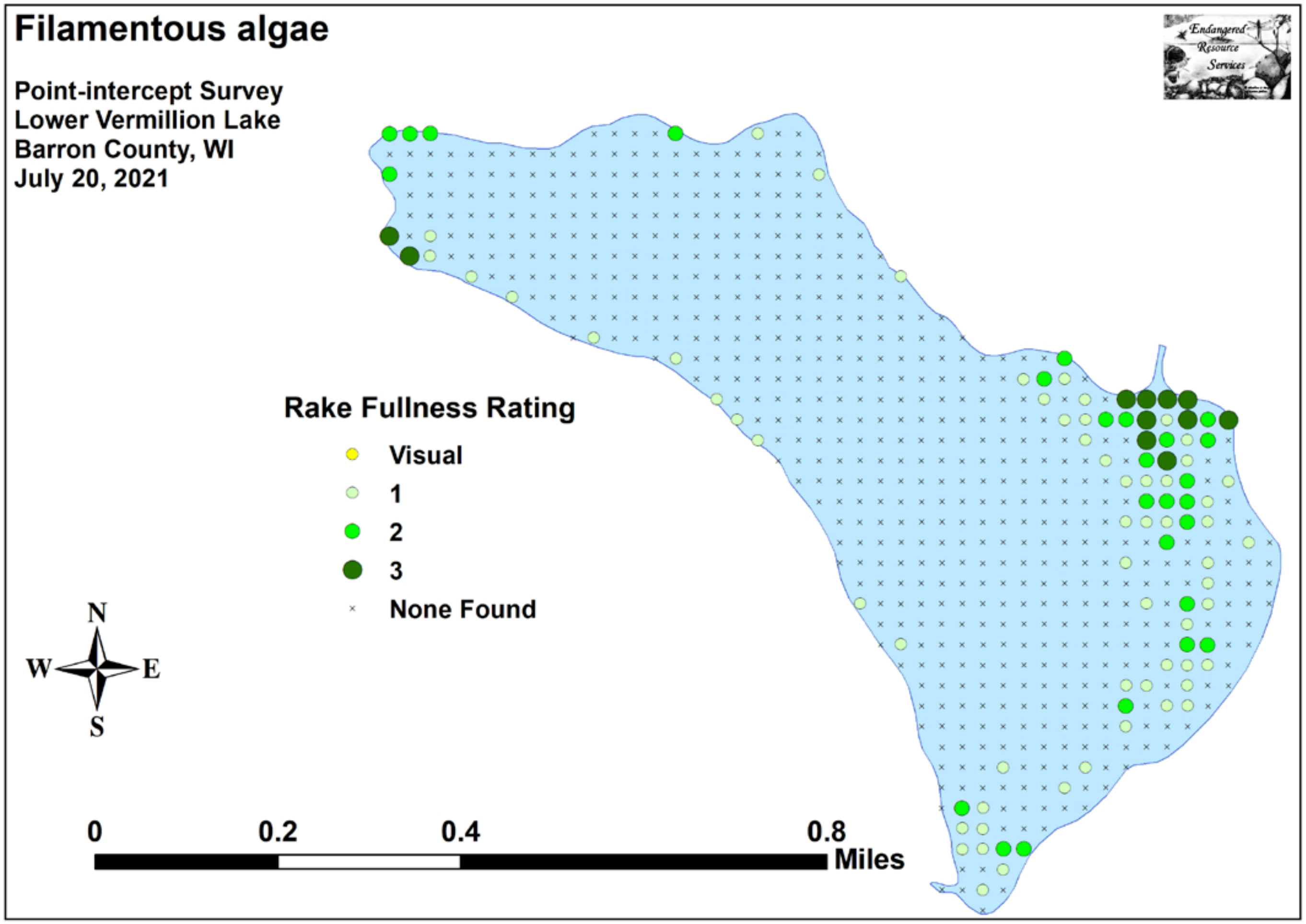

Needle spikerush
(*Eleocharis acicularis*)
Coefficient of Conservatism = 5
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

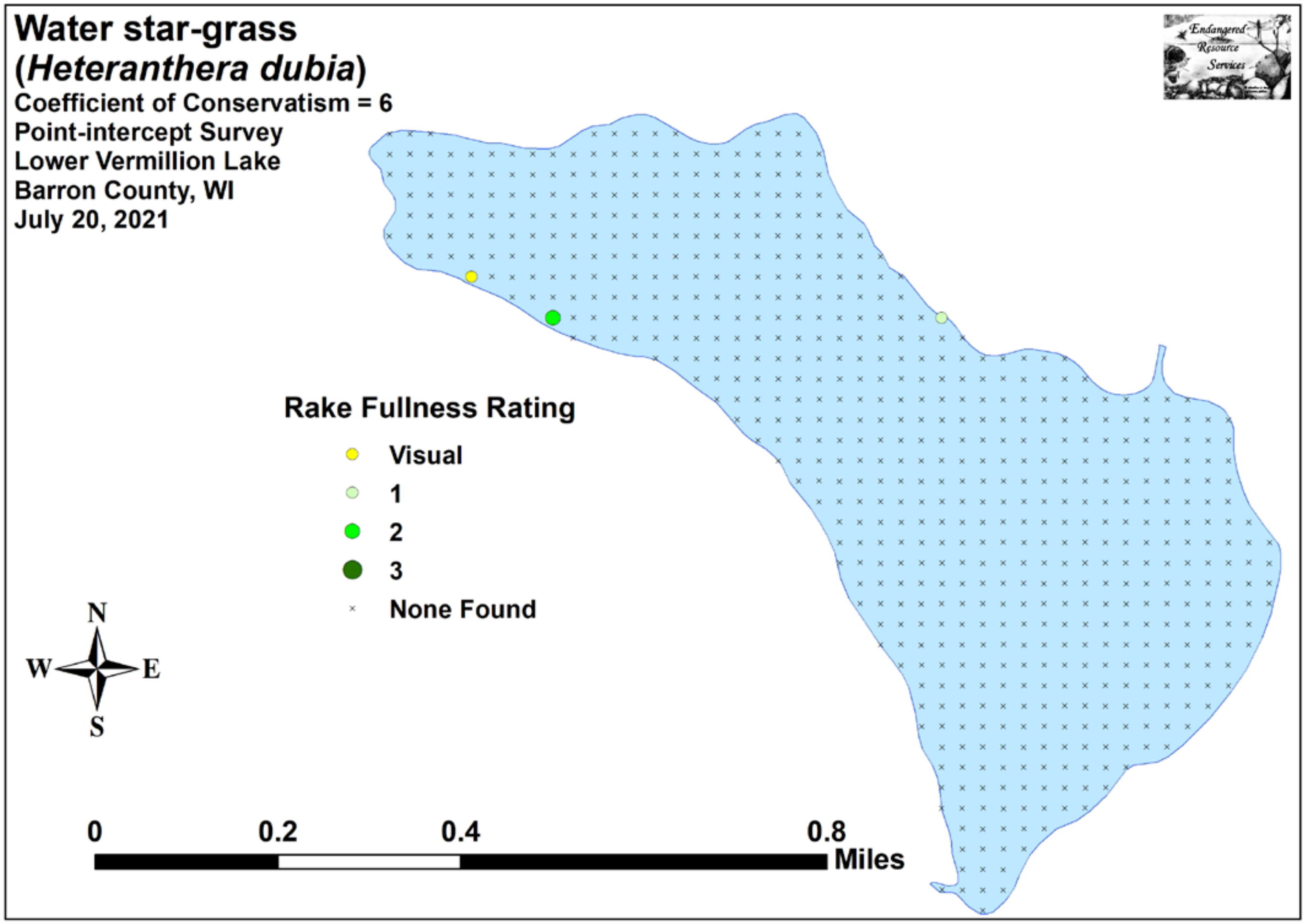


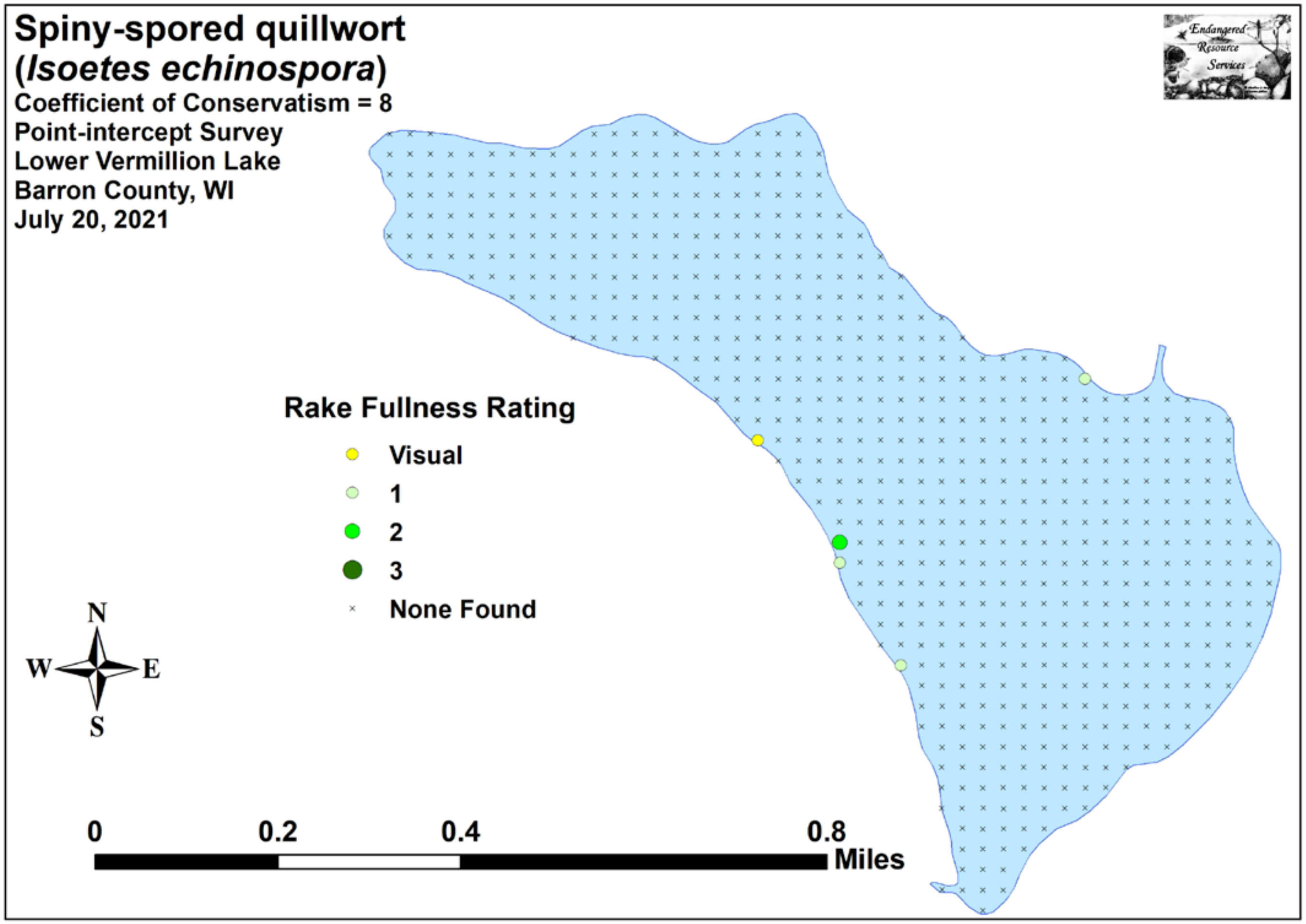
Bald spikerush
(*Eleocharis erythropoda*)
Coefficient of Conservatism = 3
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

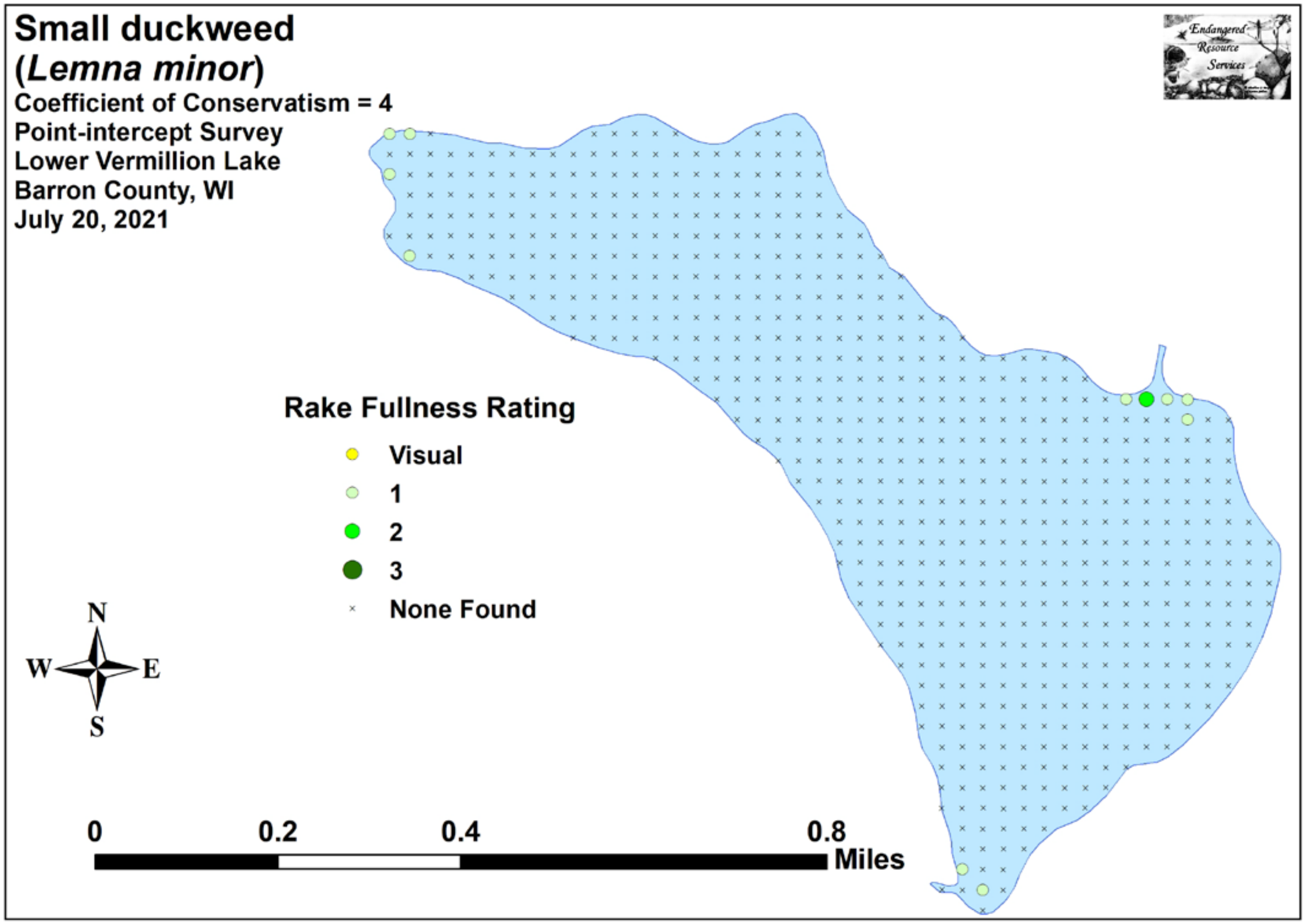


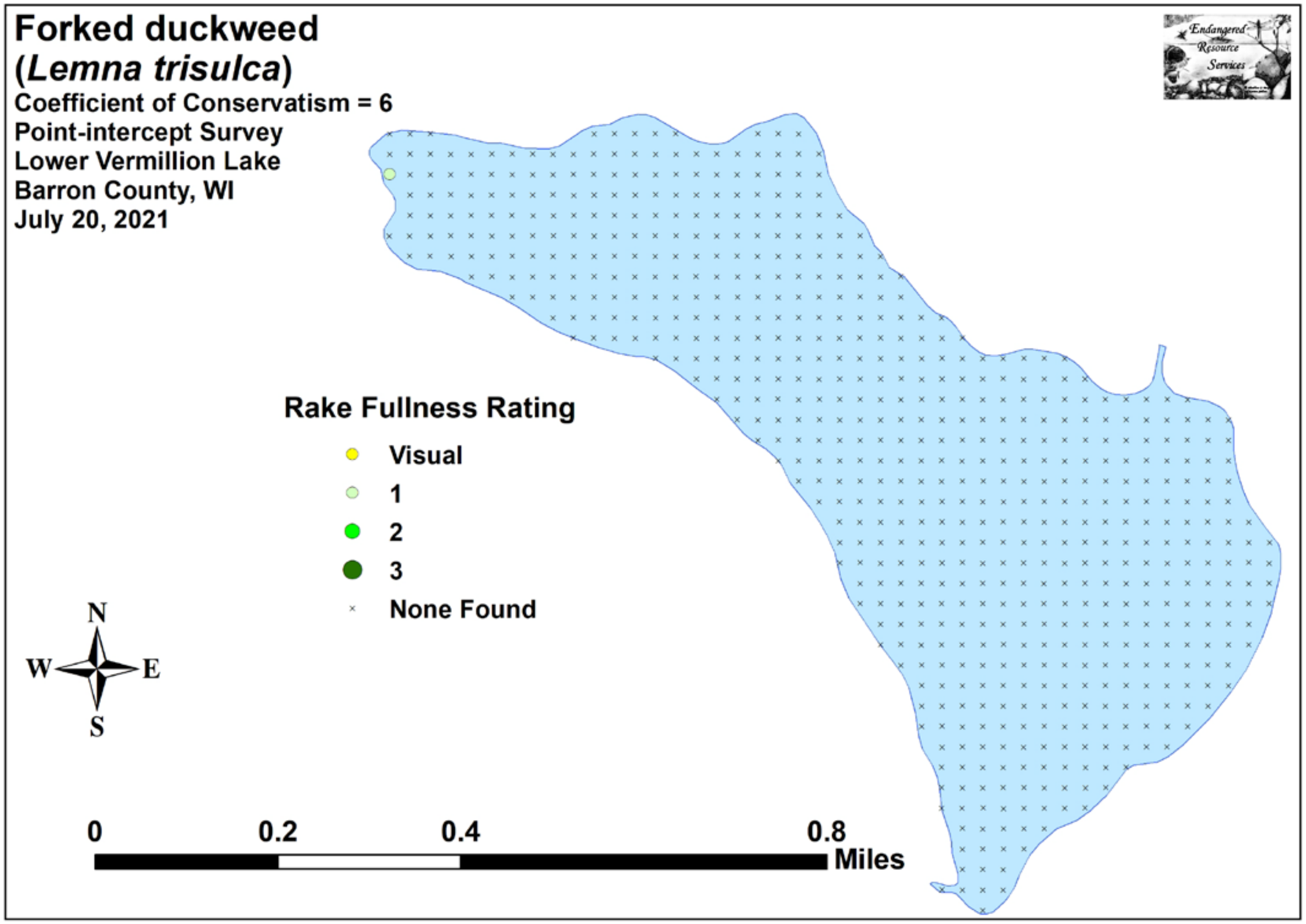
Common waterweed
(Elodea canadensis)
Coefficient of Conservatism = 3
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles

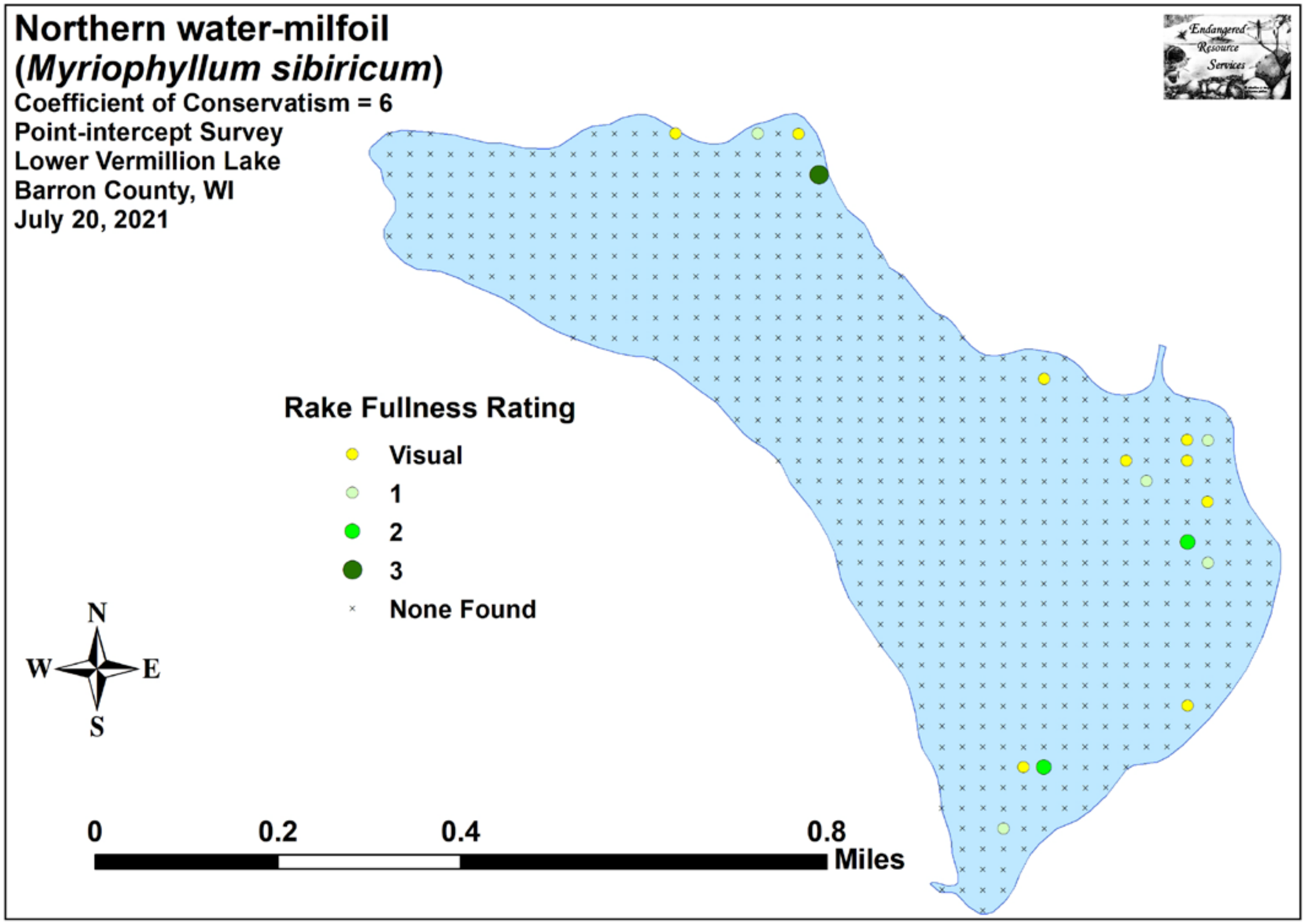

Filamentous algae
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles


Water star-grass
(Heteranthera dubia)
Coefficient of Conservatism = 6
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles


Spiny-spored quillwort
(*Isoetes echinospora*)
Coefficient of Conservatism = 8
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles


Small duckweed
(Lemna minor)
Coefficient of Conservatism = 4
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles


Forked duckweed
(Lemna trisulca)
Coefficient of Conservatism = 6
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
E
S
0
0.2
0.4
0.8
Miles


Northern water-milfoil
(Myriophyllum sibiricum)
Coefficient of Conservatism = 6
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
1
2
3
None Found
N
W
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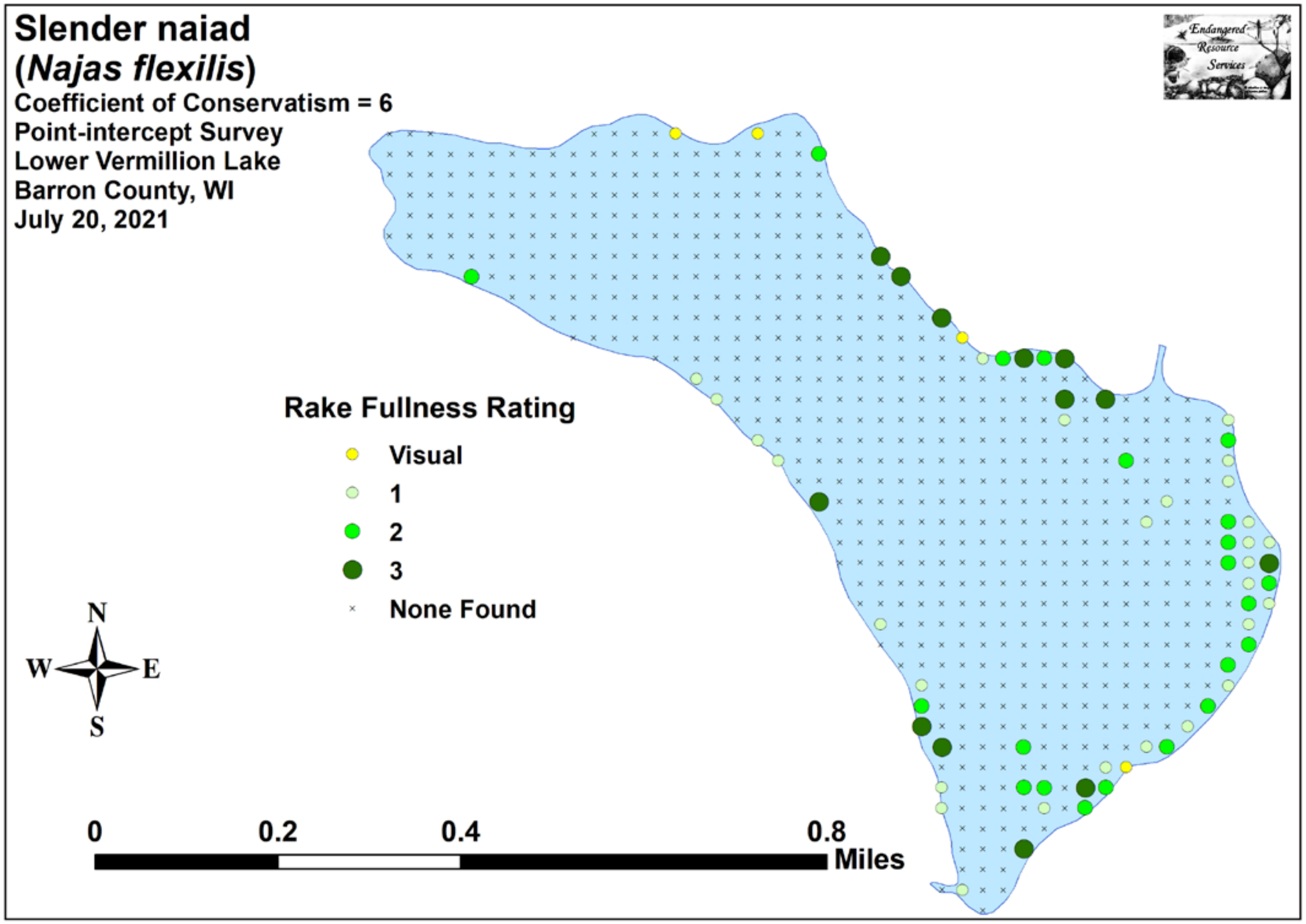
Miles


Slender naiad
(Najas flexilis)
Coefficient of Conservatism = 6
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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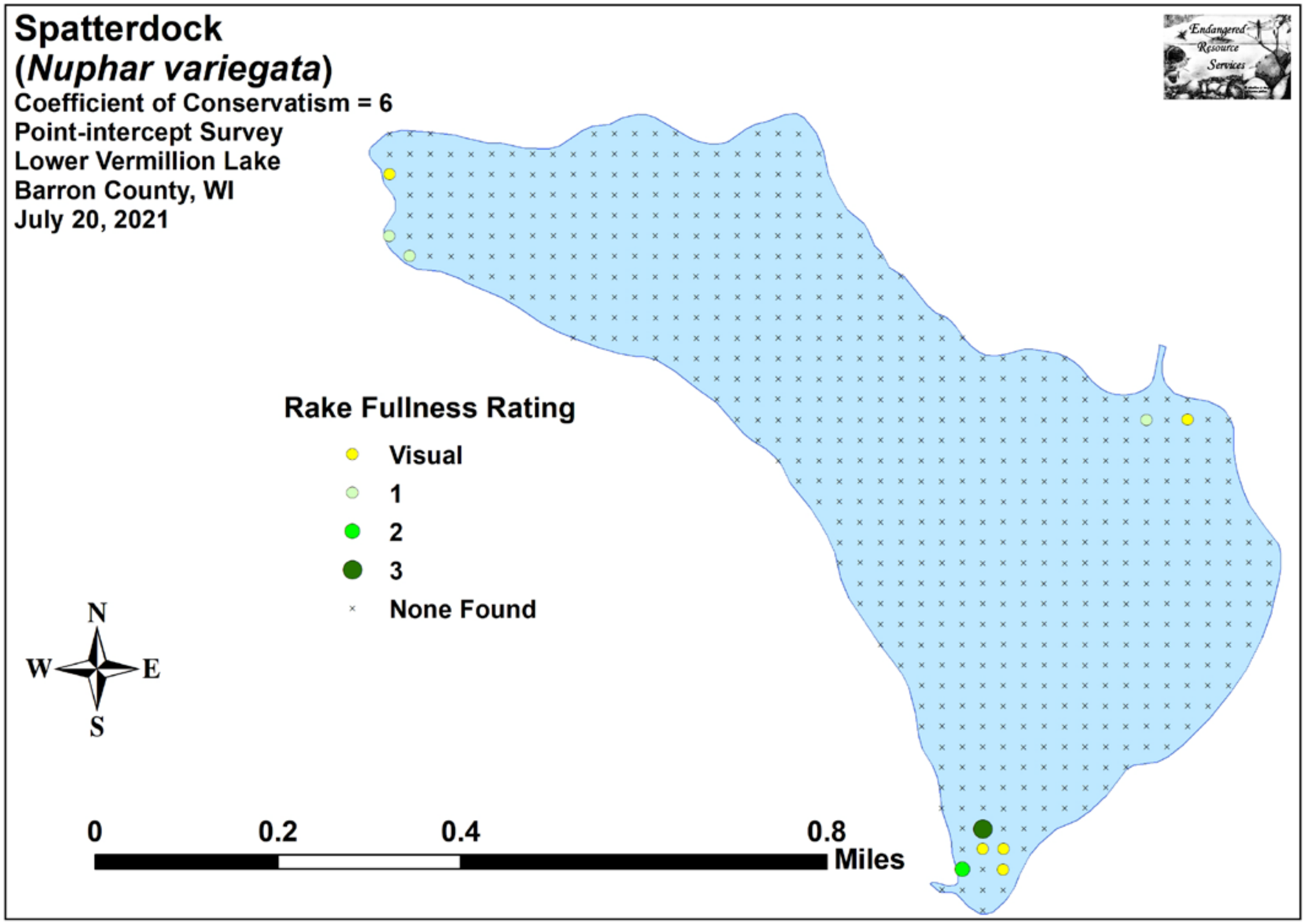
Spatterdock
(Nuphar variegata)
Coefficient of Conservatism = 6
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
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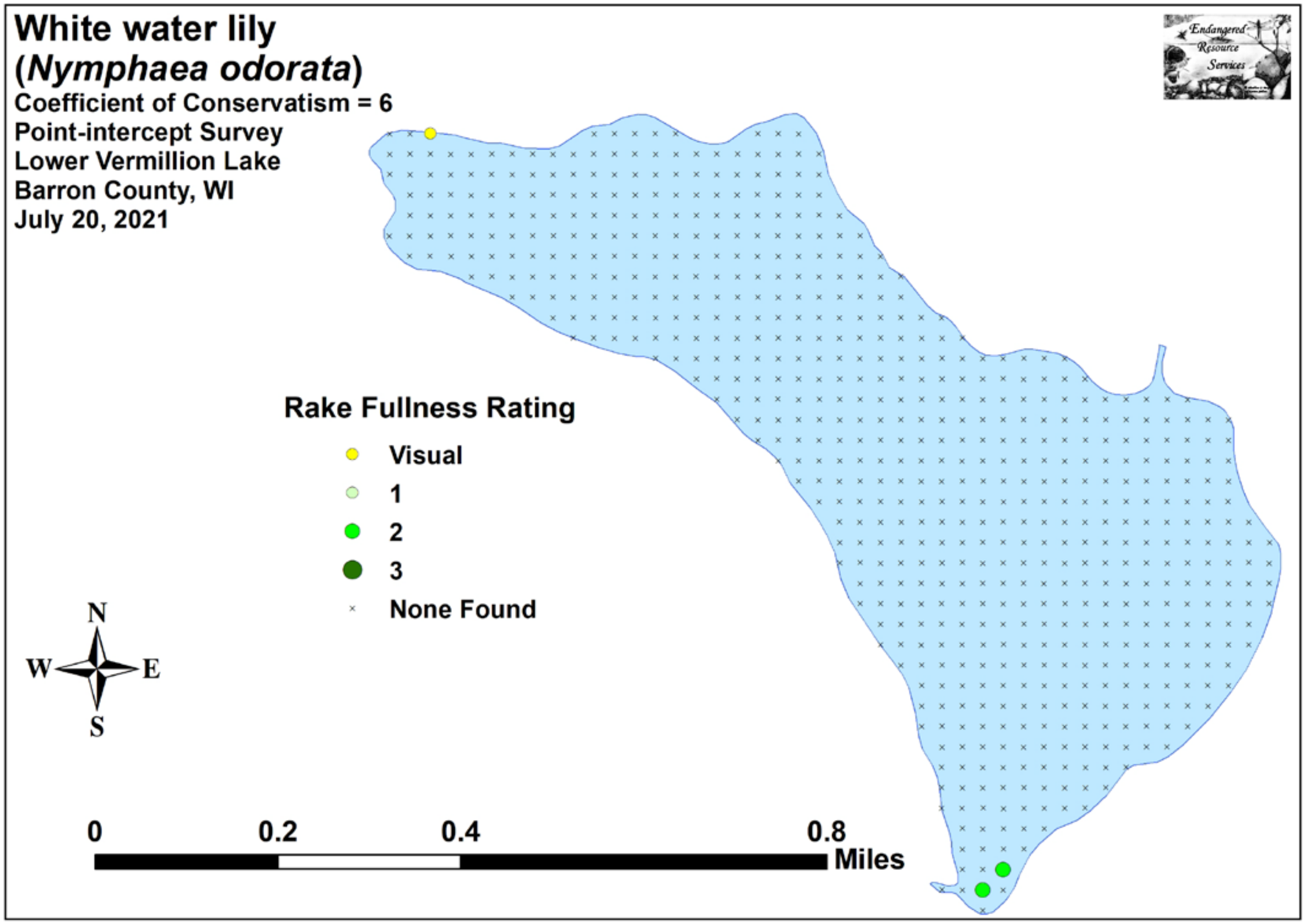
Miles


White water lily
(*Nymphaea odorata*)
Coefficient of Conservatism = 6
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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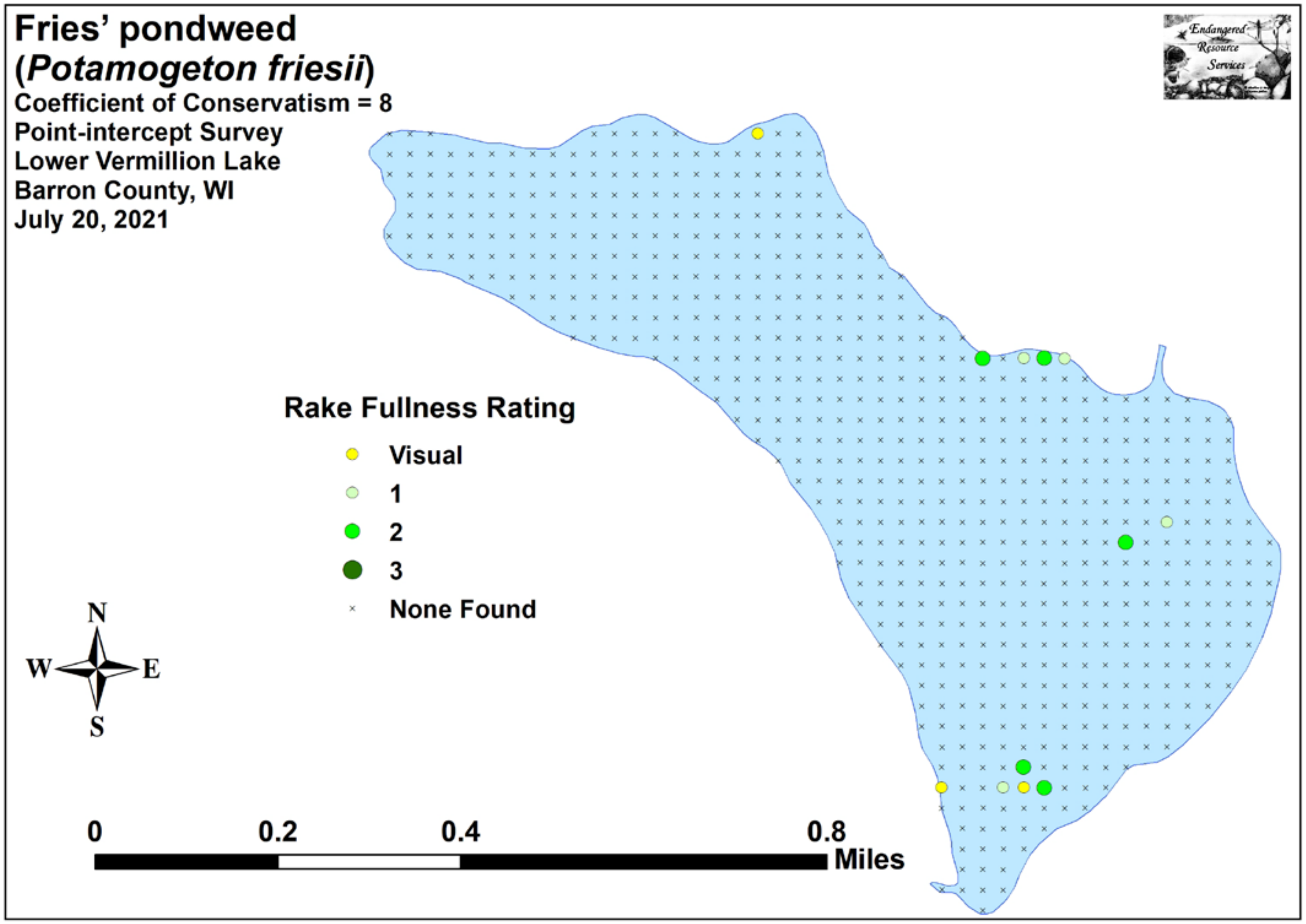
Fries' pondweed
(Potamogeton friesii)
Coefficient of Conservatism = 8
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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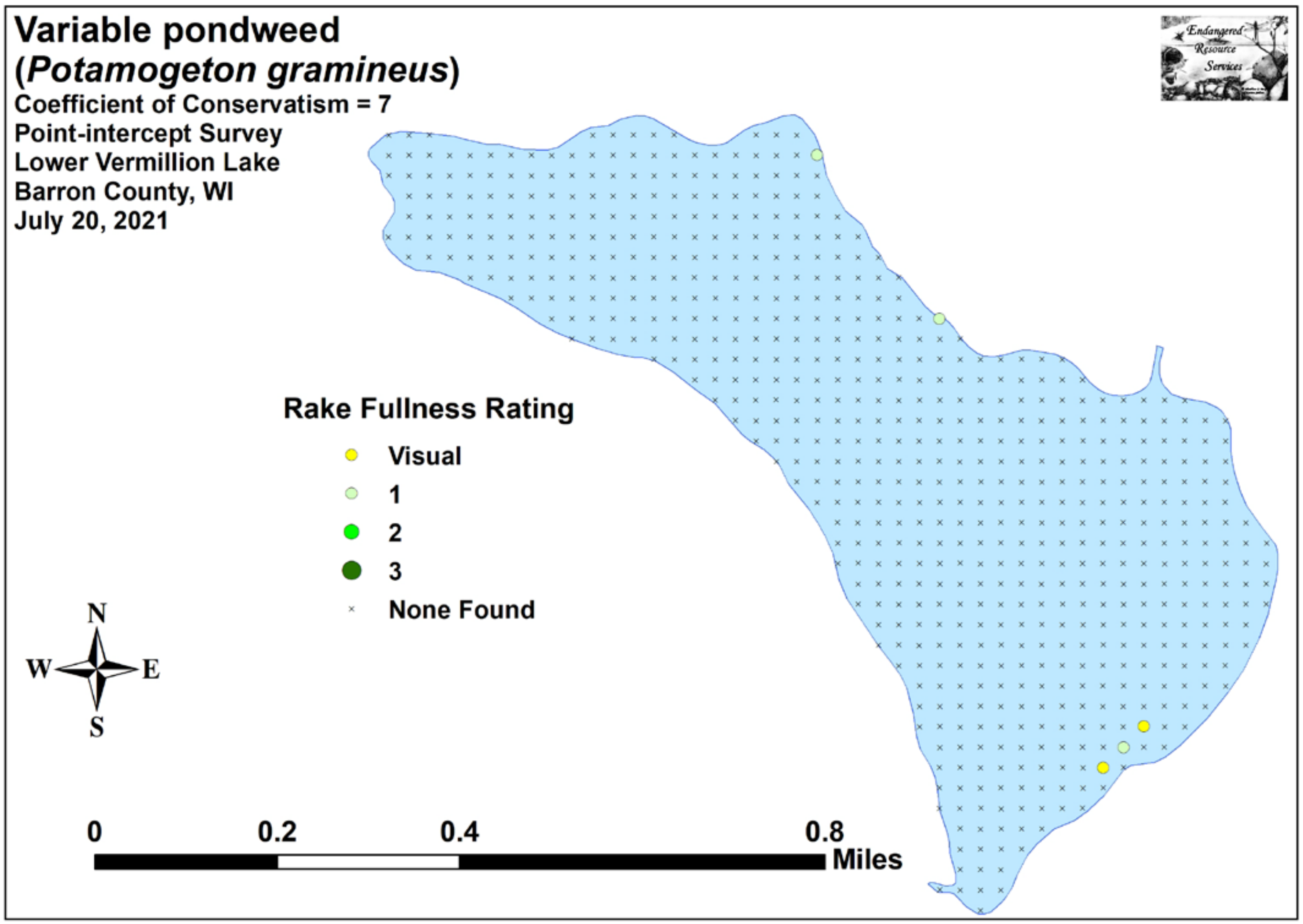

Variable pondweed
(*Potamogeton gramineus*)
Coefficient of Conservatism = 7
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
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None Found
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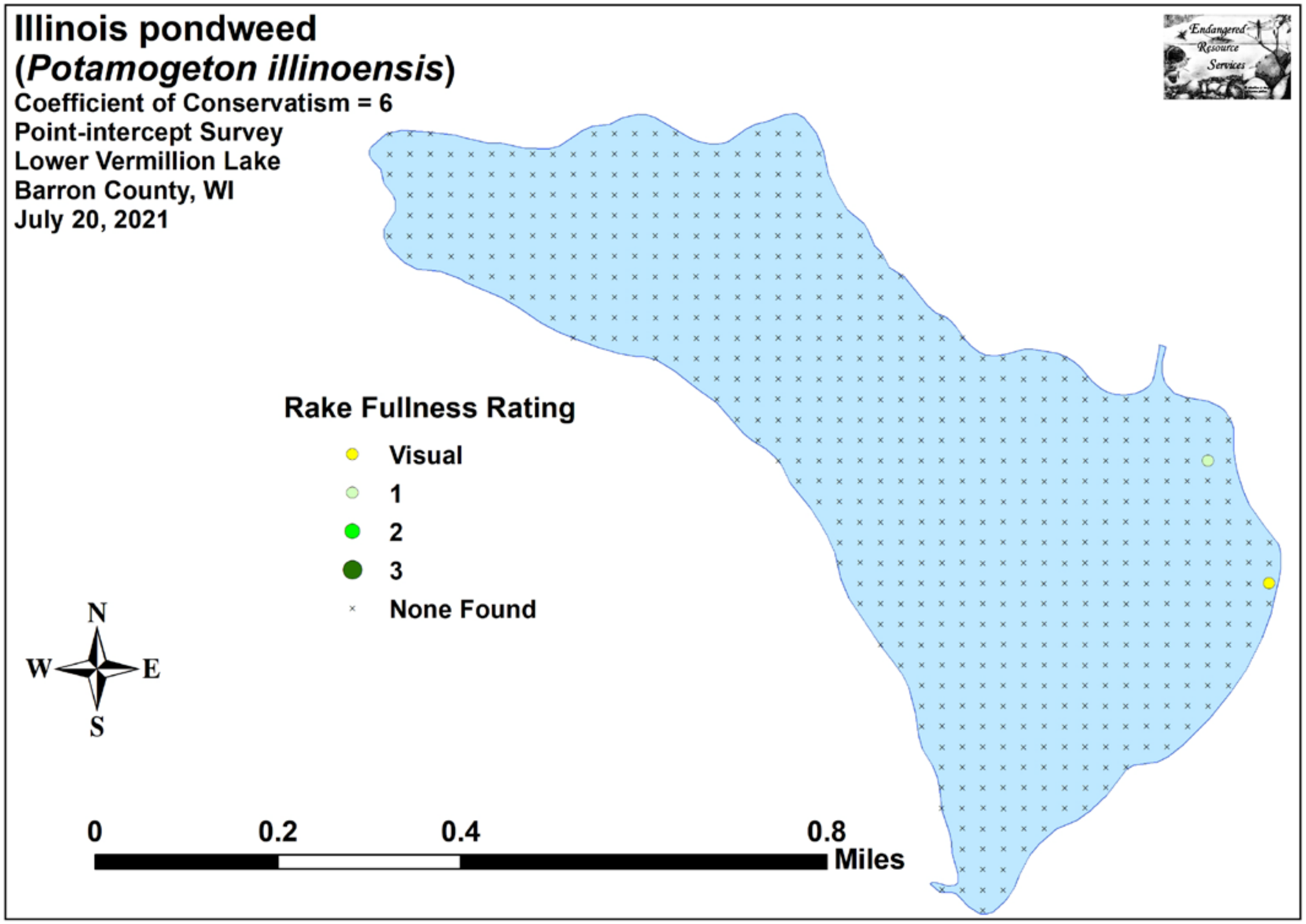
Illinois pondweed
(*Potamogeton illinoensis*)
Coefficient of Conservatism = 6
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
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None Found
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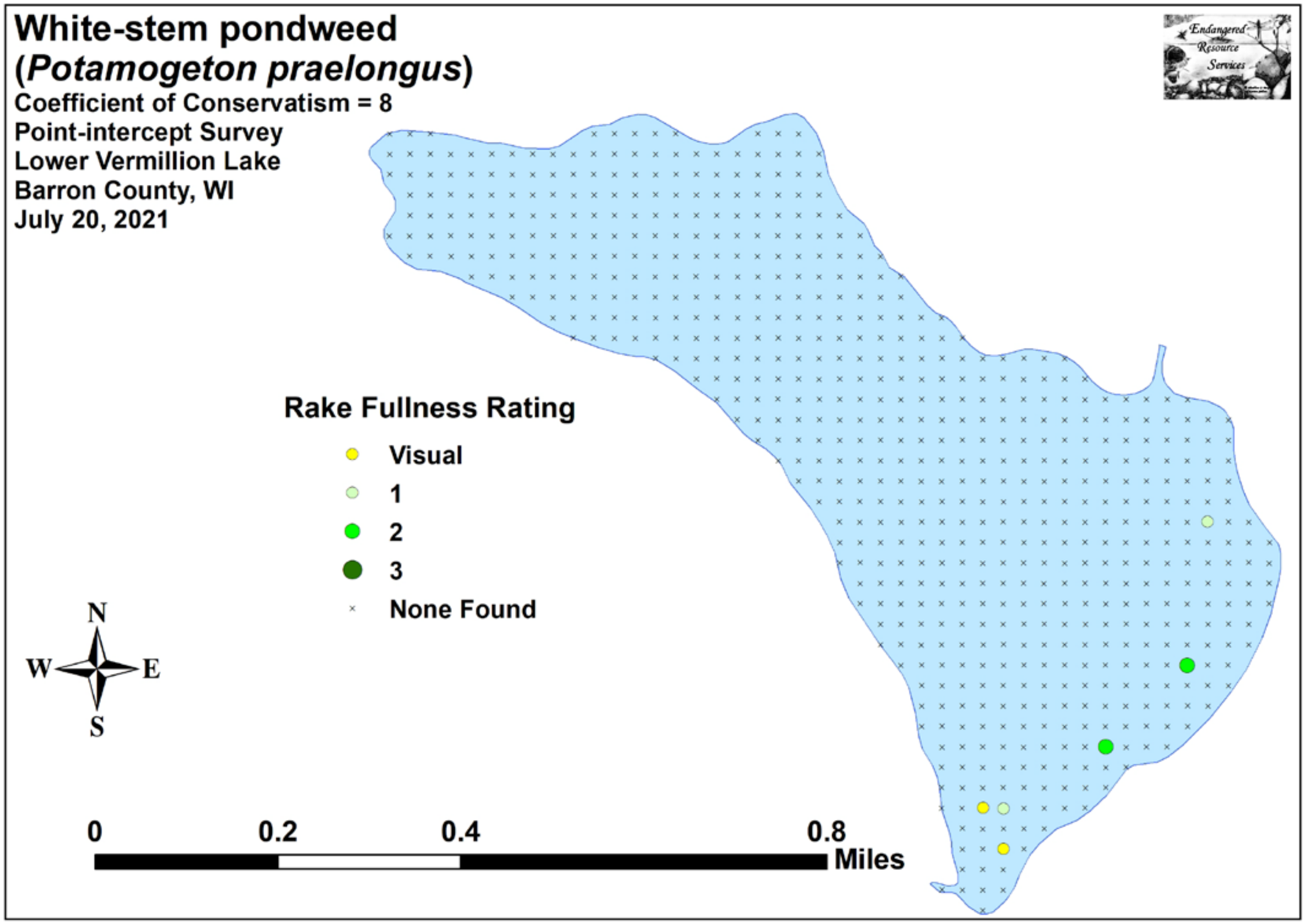
Miles


White-stem pondweed
(*Potamogeton praelongus*)
Coefficient of Conservatism = 8
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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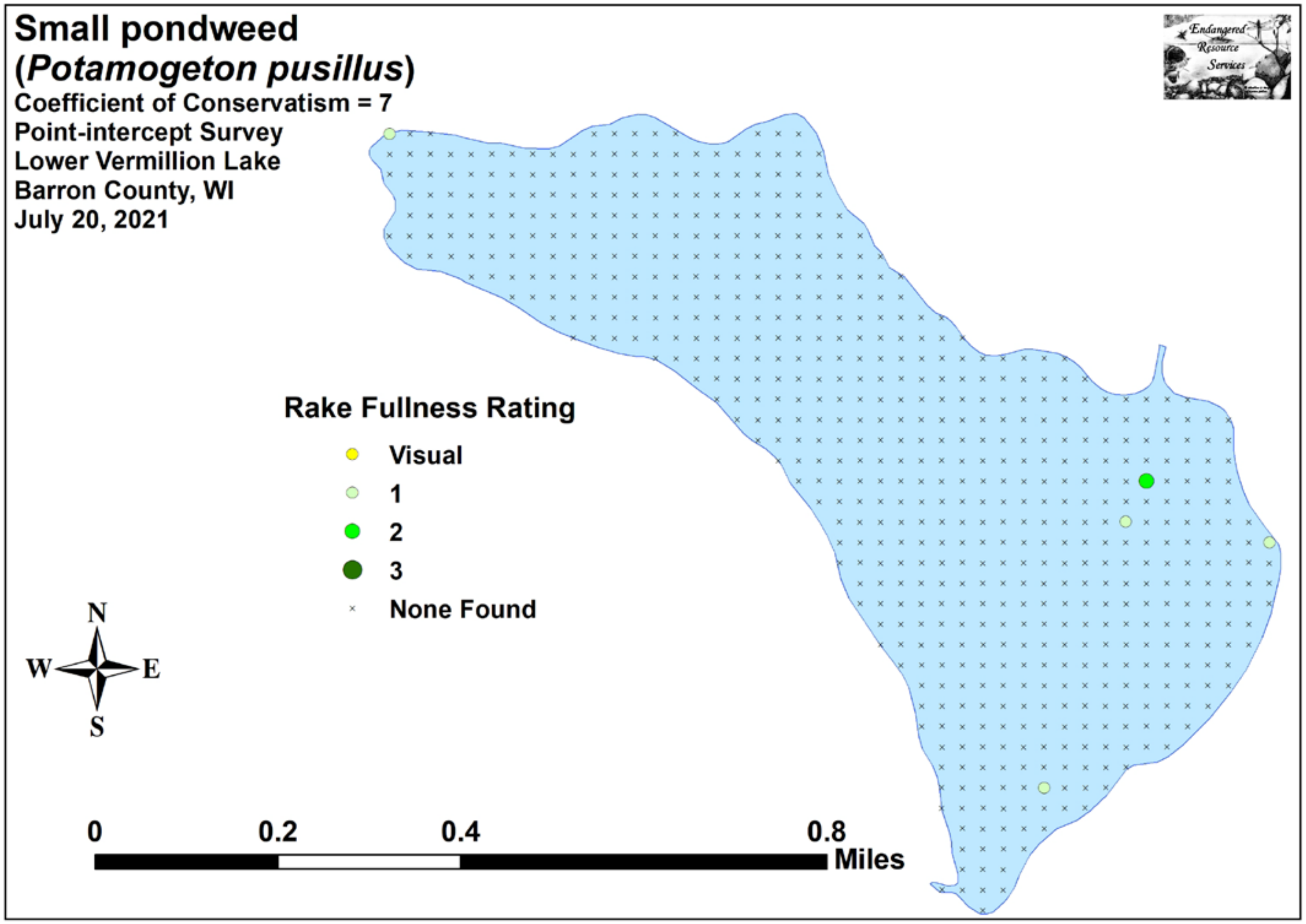
Miles


Small pondweed
(Potamogeton pusillus)
Coefficient of Conservatism = 7
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
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None Found
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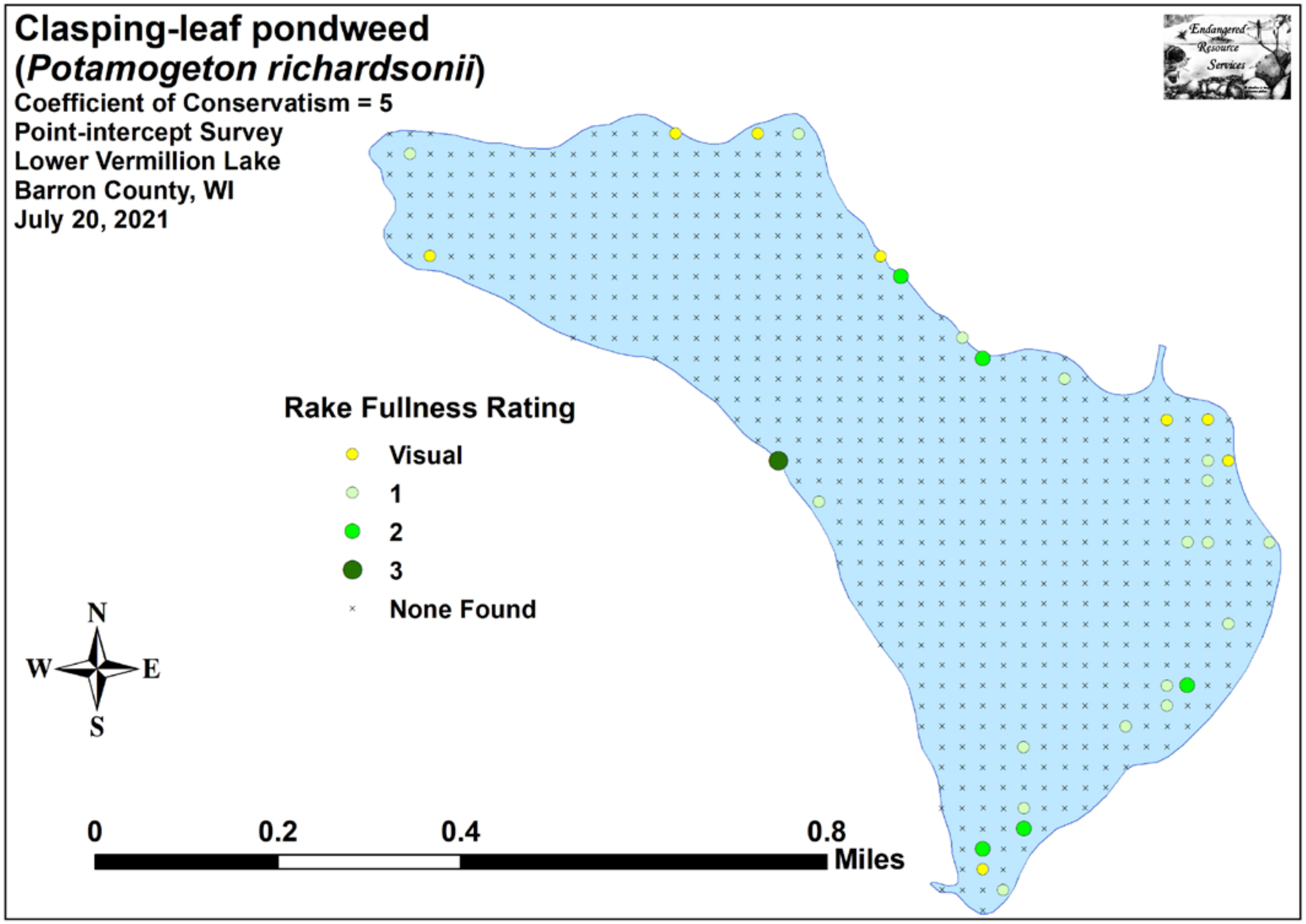
Clasping-leaf pondweed
(Potamogeton richardsonii)
Coefficient of Conservatism = 5
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
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None Found
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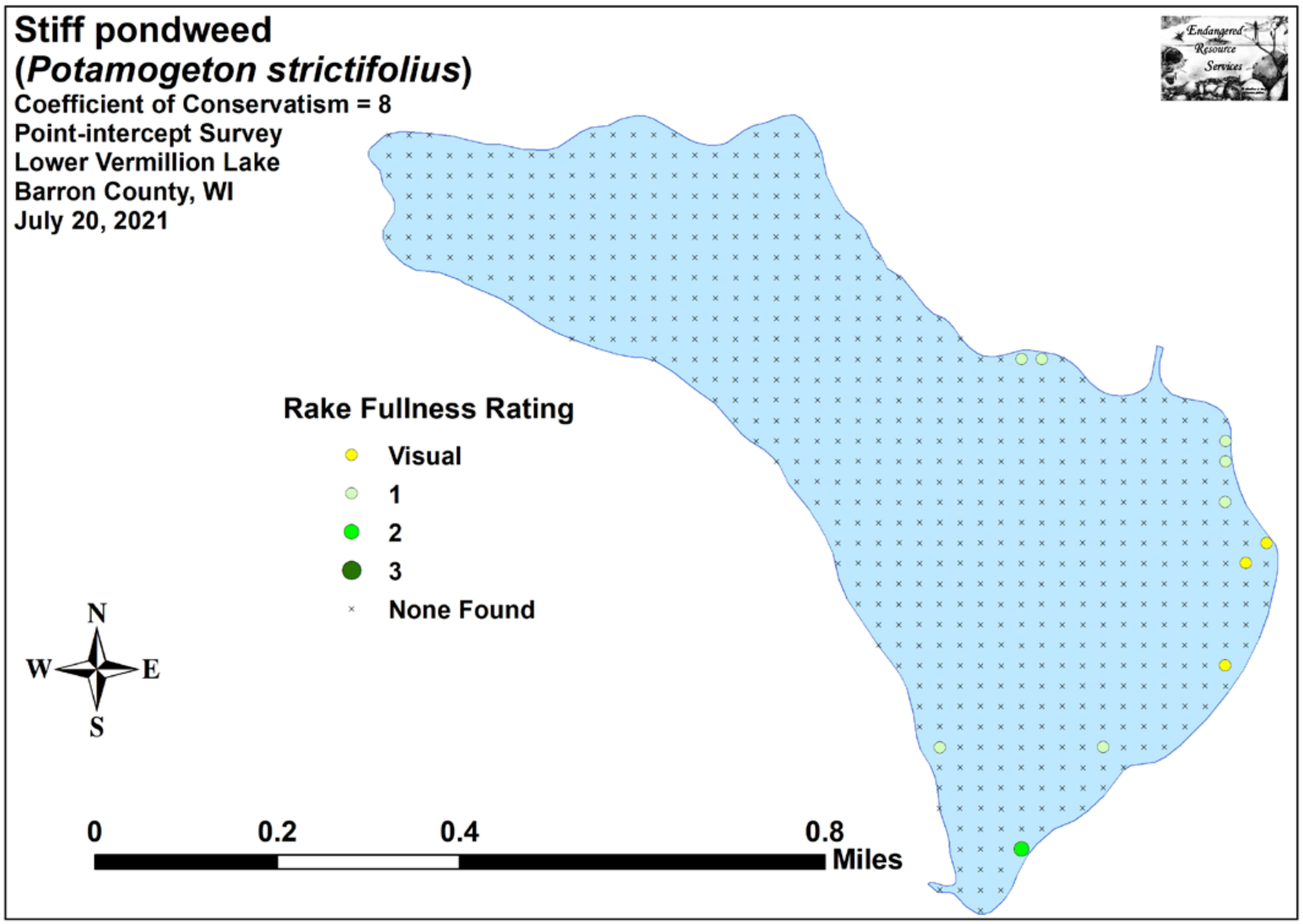
Stiff pondweed
(Potamogeton strictifolius)
Coefficient of Conservatism = 8
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
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None Found
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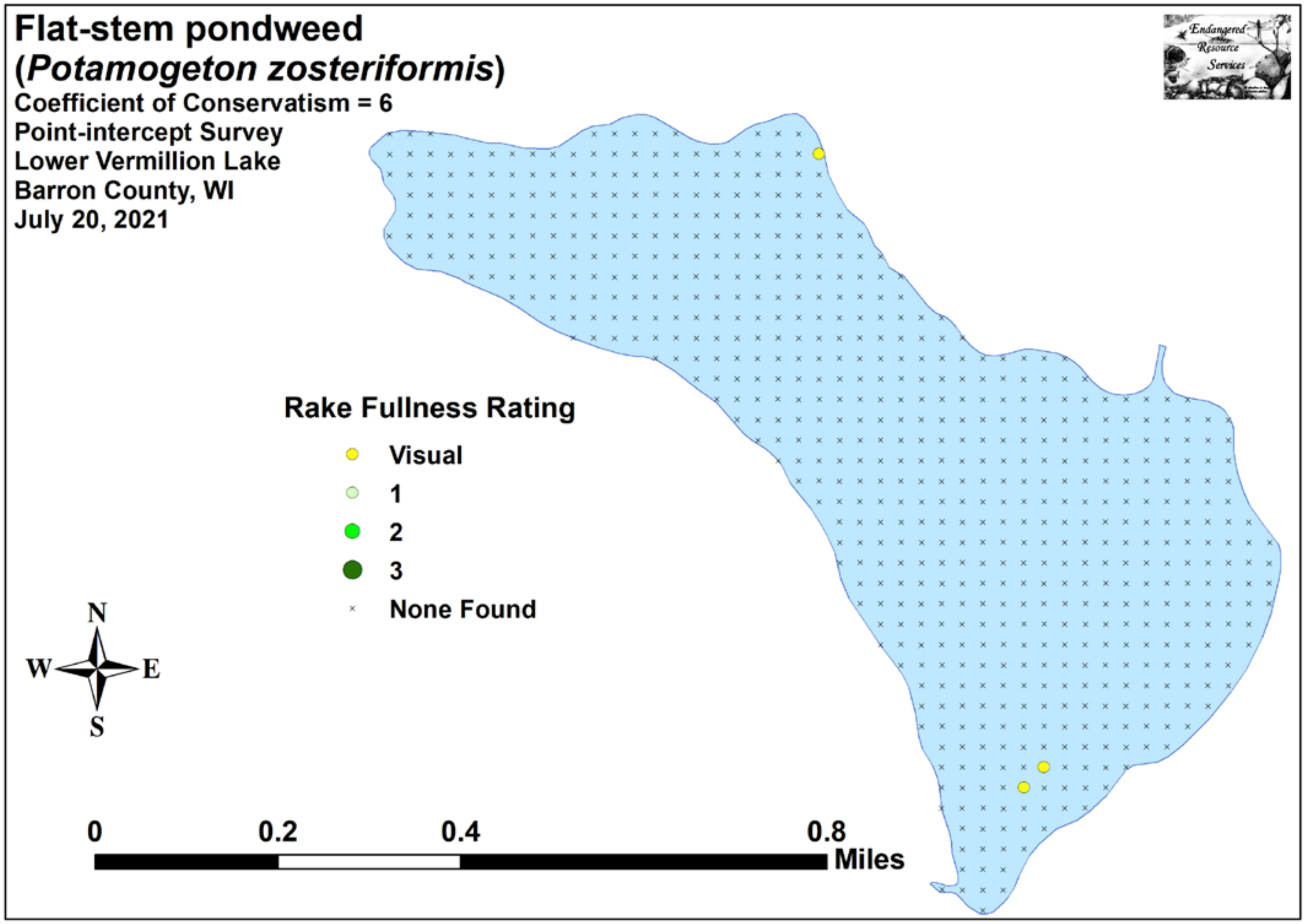
Flat-stem pondweed
(Potamogeton zosteriformis)
Coefficient of Conservatism = 6
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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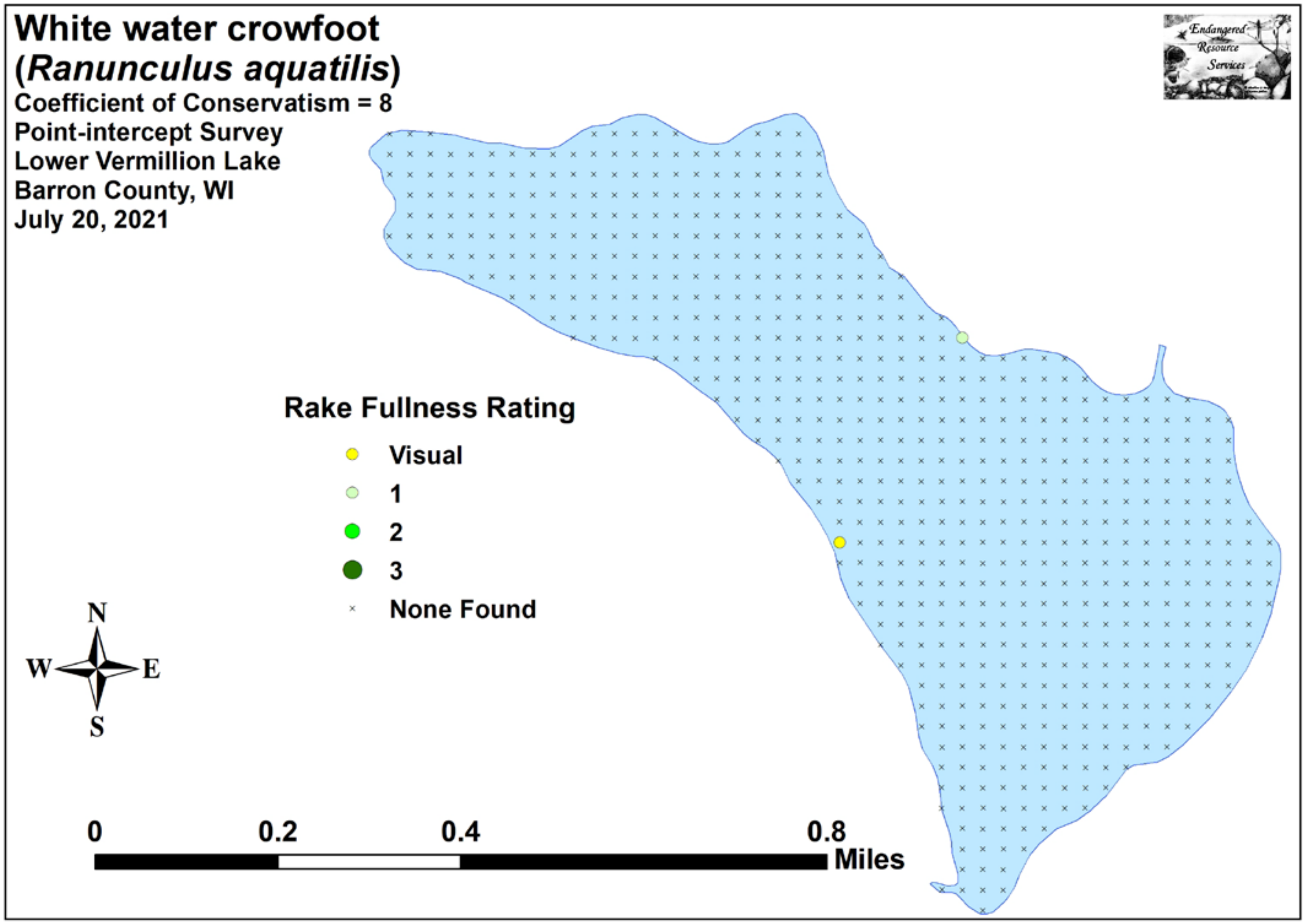
White water crowfoot
(*Ranunculus aquatilis*)
Coefficient of Conservatism = 8
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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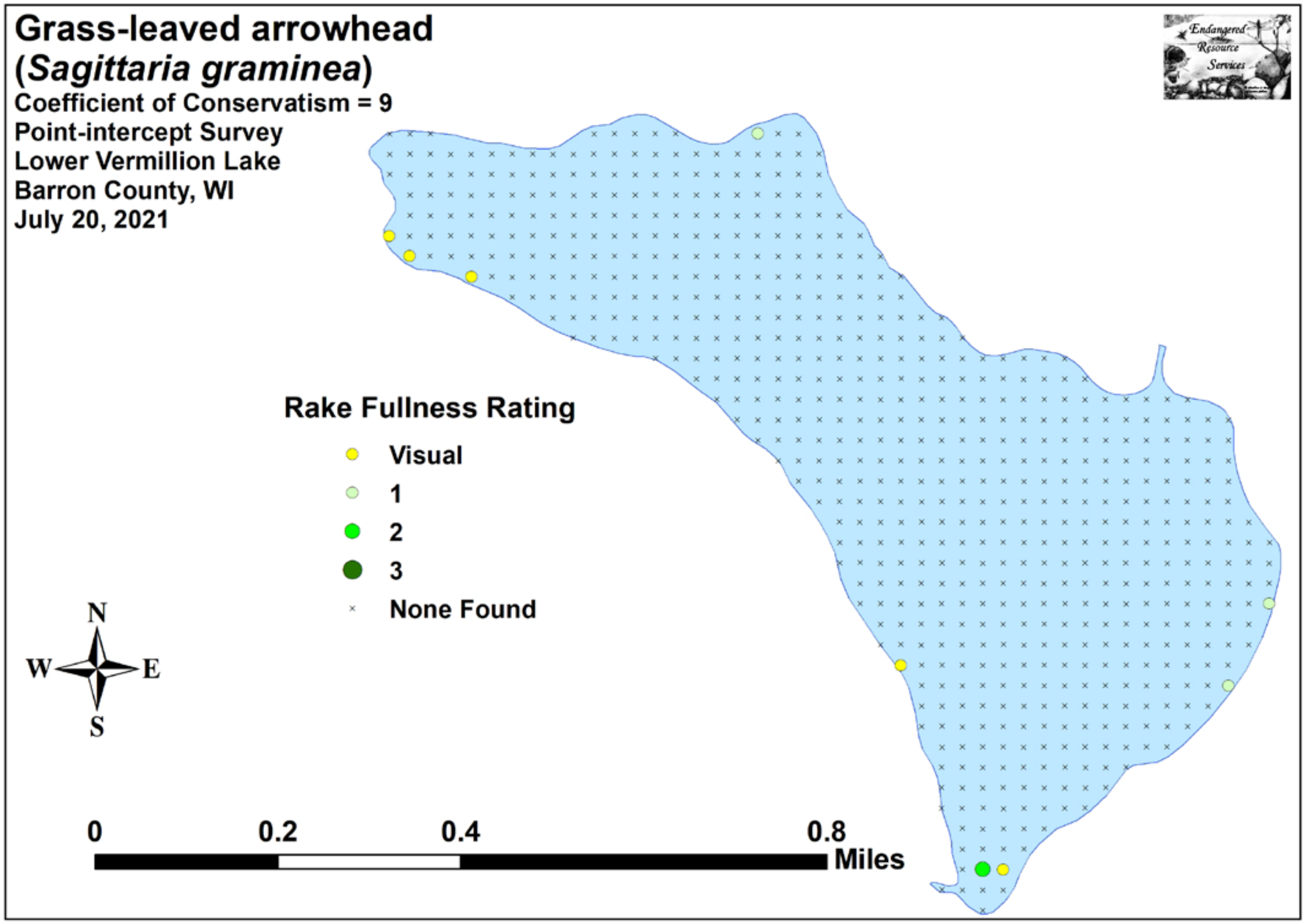
Grass-leaved arrowhead
(Sagittaria graminea)
Coefficient of Conservatism = 9
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
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None Found
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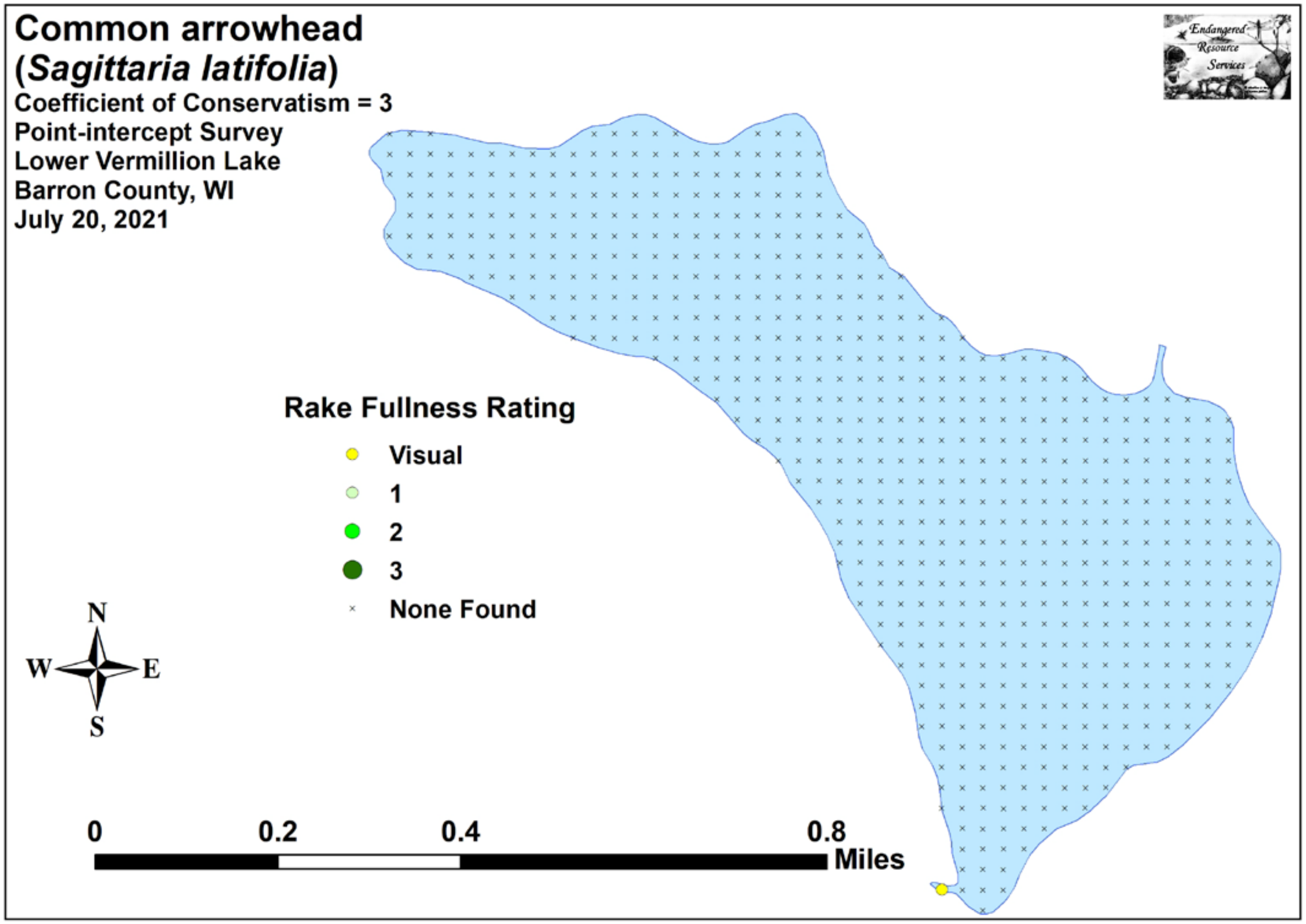
Common arrowhead
(*Sagittaria latifolia*)
Coefficient of Conservatism = 3
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
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None Found
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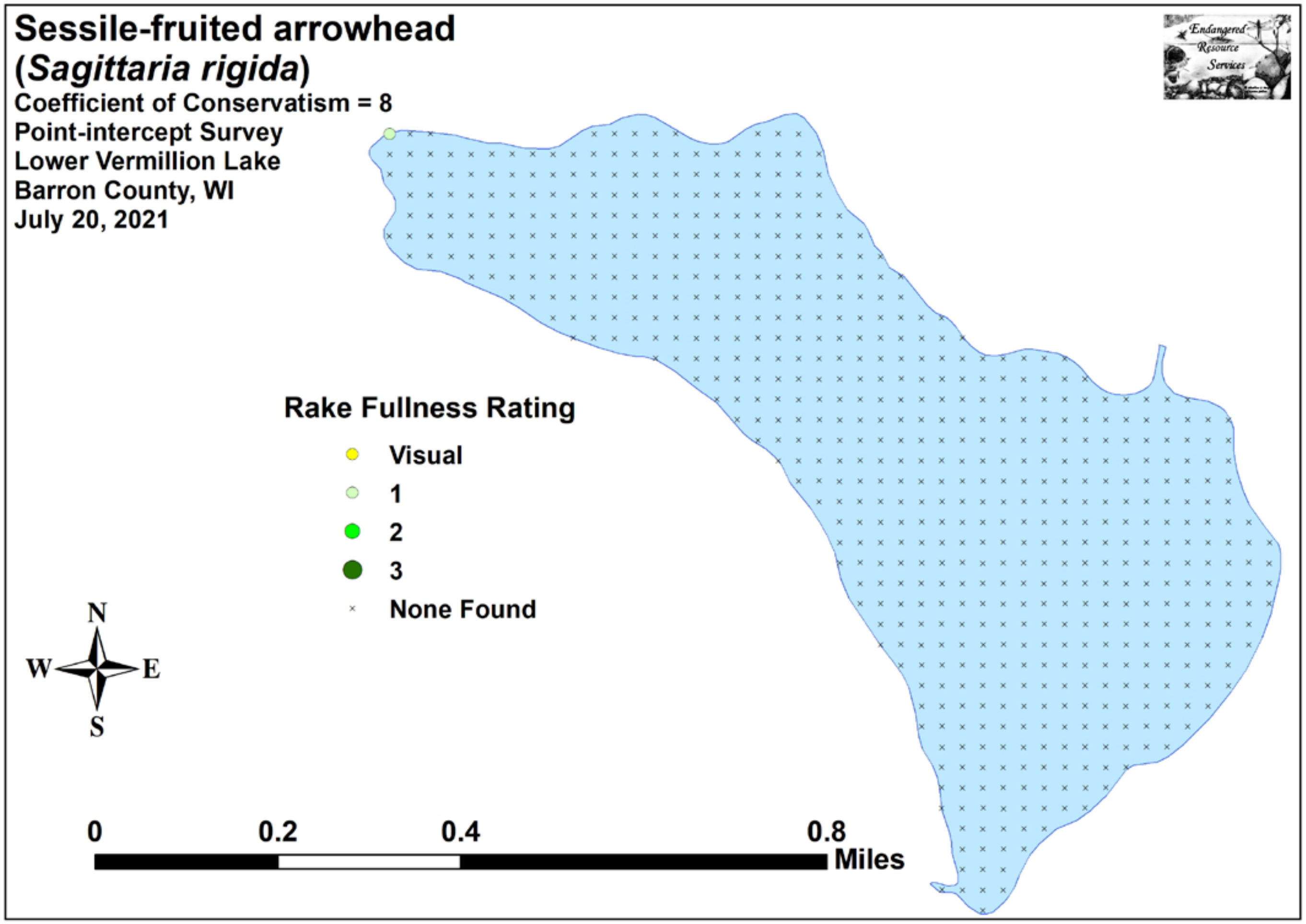
Sessile-fruited arrowhead
(*Sagittaria rigida*)
Coefficient of Conservatism = 8
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
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None Found
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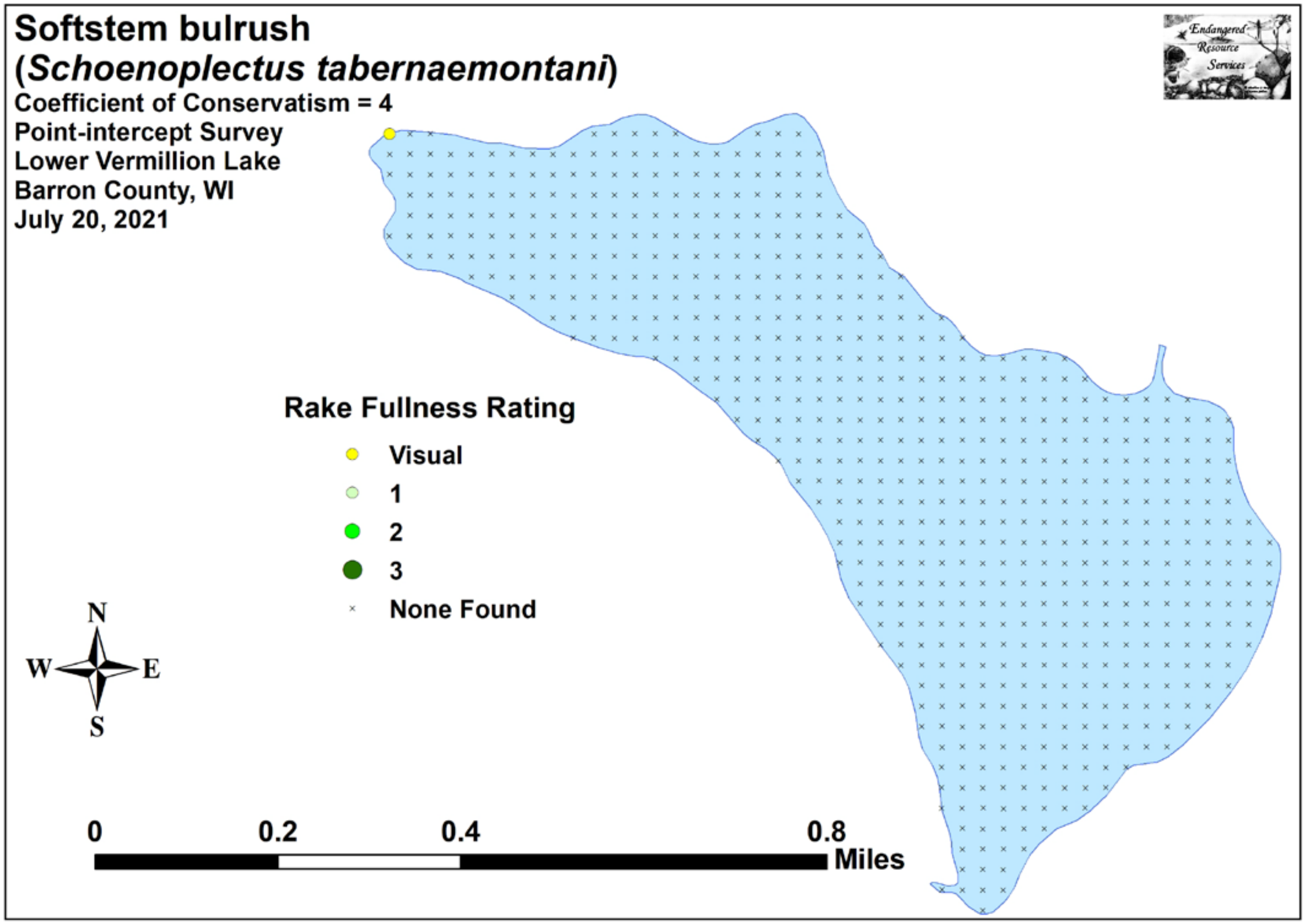
Miles
Endangered Resource Services


Softstem bulrush
(Schoenoplectus tabernaemontani)
Coefficient of Conservatism = 4
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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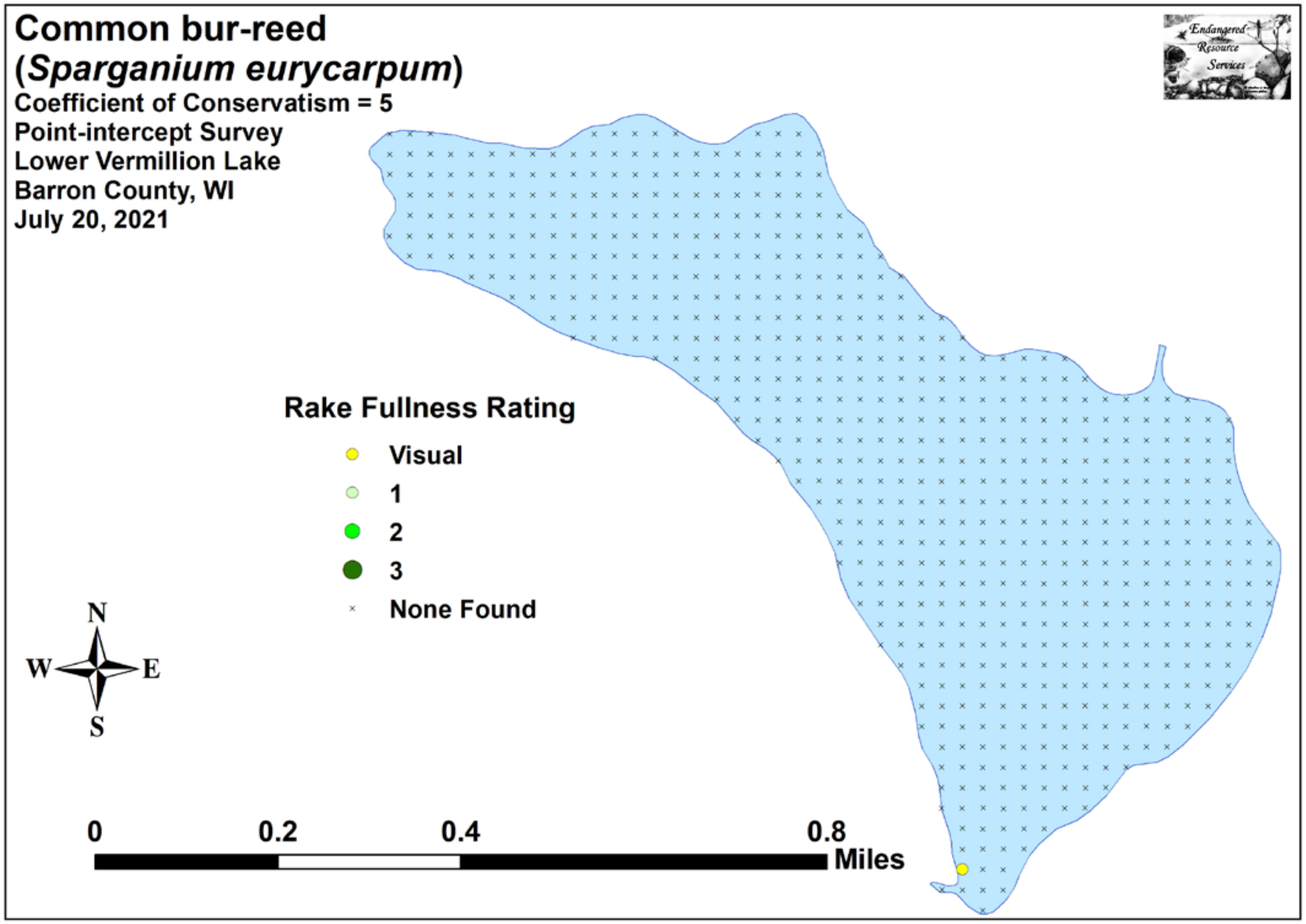
Common bur-reed
(Sparganium eurycarpum)
Coefficient of Conservatism = 5
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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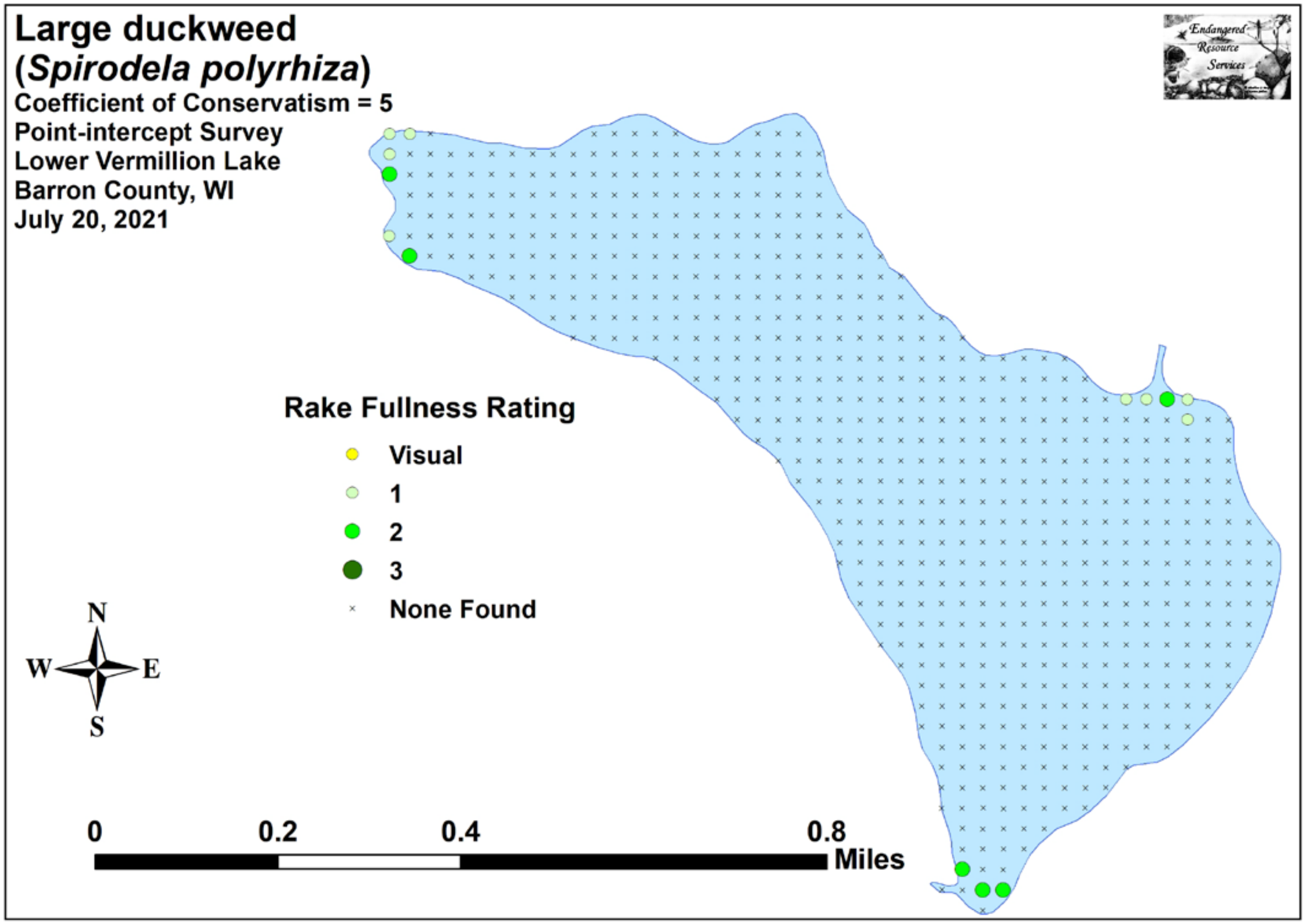
Large duckweed
(*Spirodela polyrhiza*)
Coefficient of Conservatism = 5
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
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None Found
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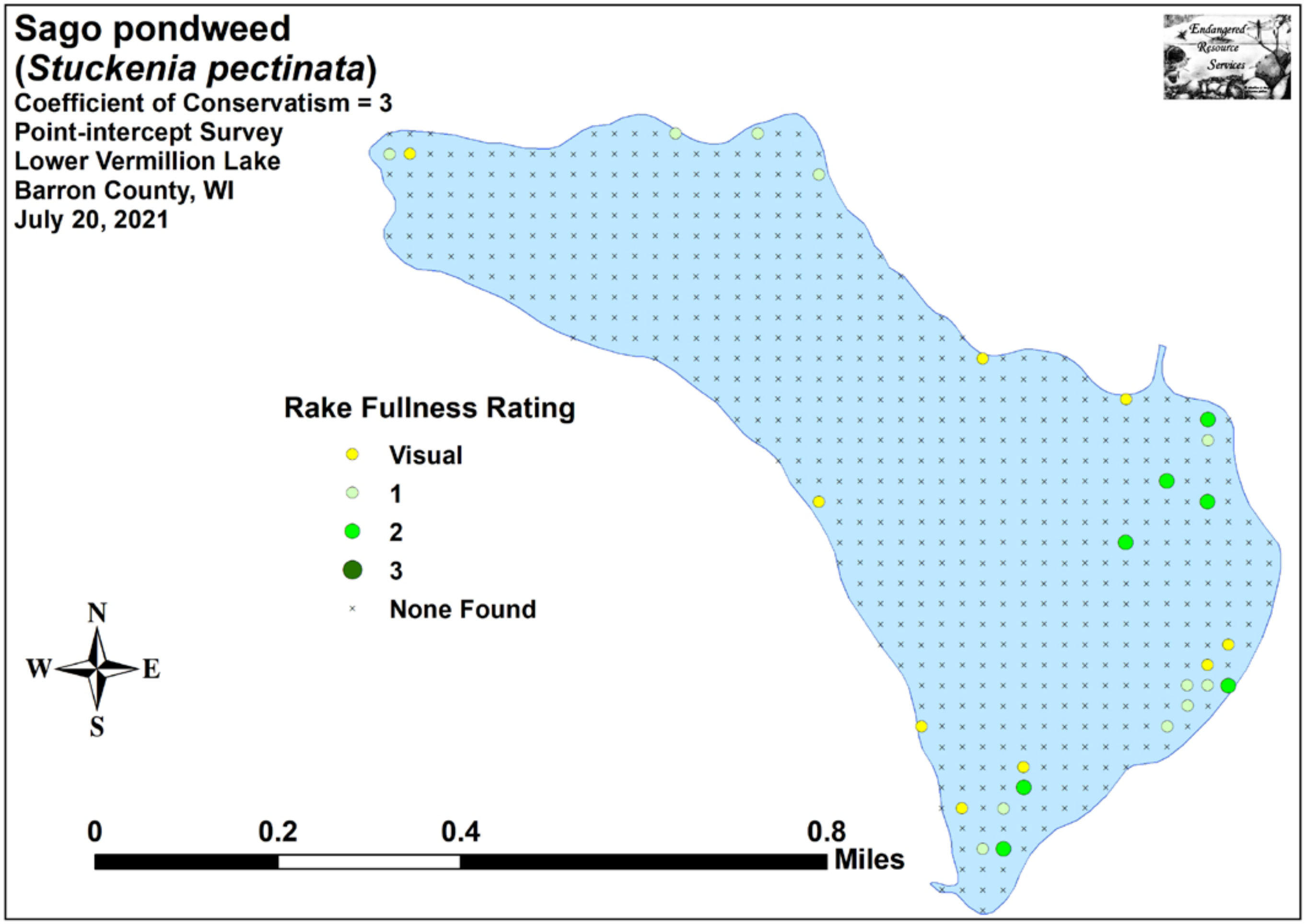
Sago pondweed
(Stuckenia pectinata)
Coefficient of Conservatism = 3
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
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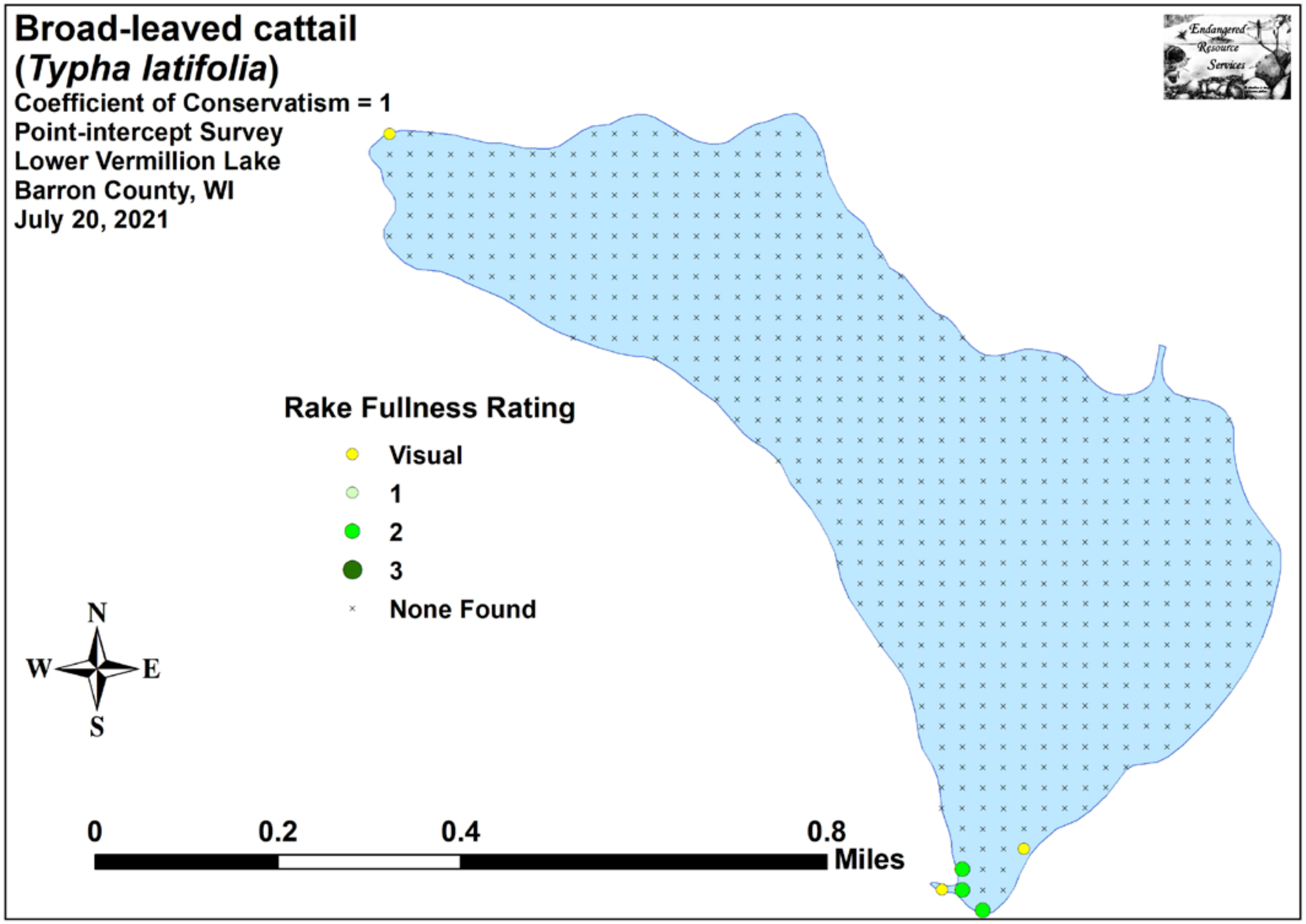
Broad-leaved cattail
(*Typha latifolia*)
Coefficient of Conservatism = 1
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
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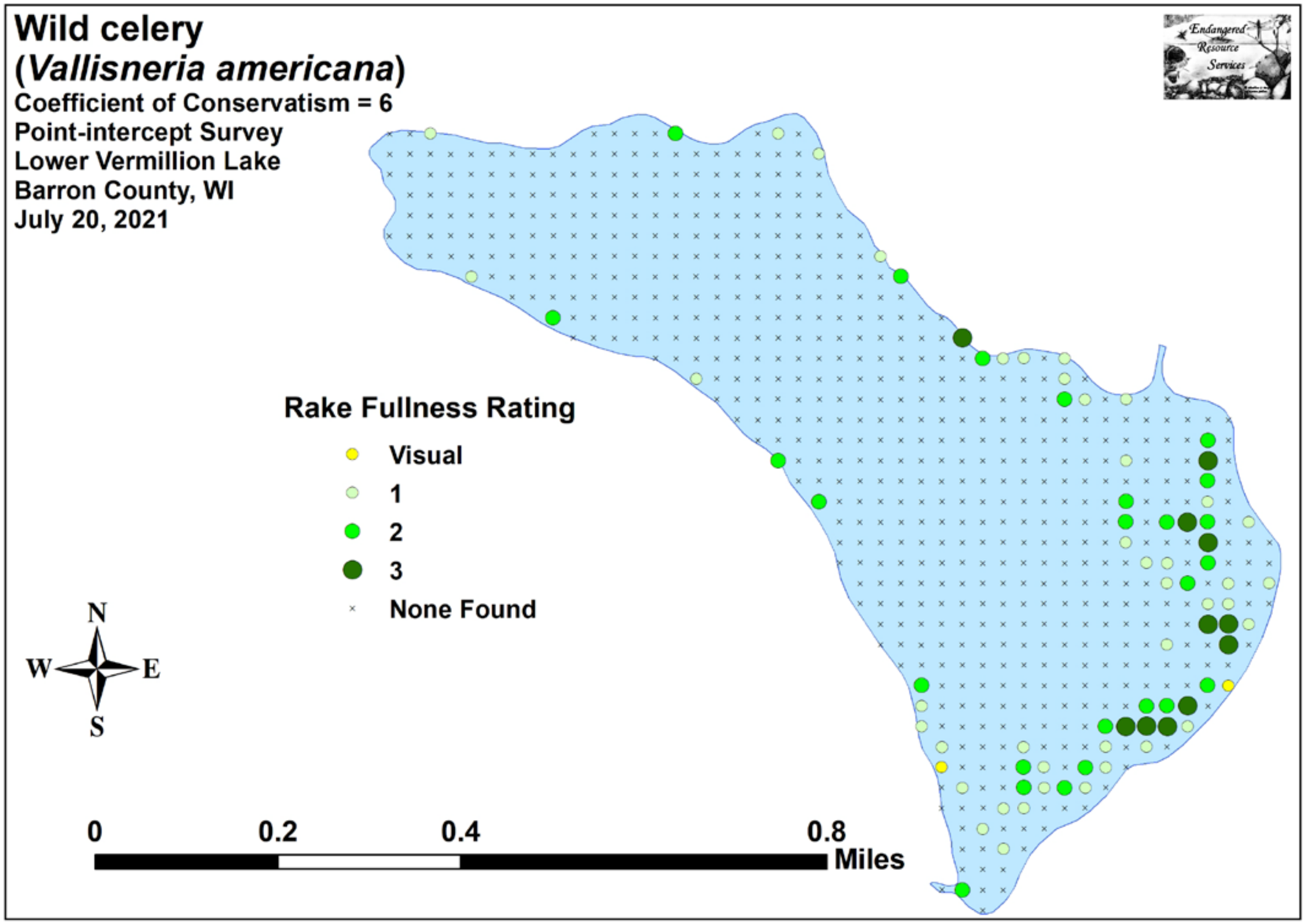
Wild celery
(*Vallisneria americana*)
Coefficient of Conservatism = 6
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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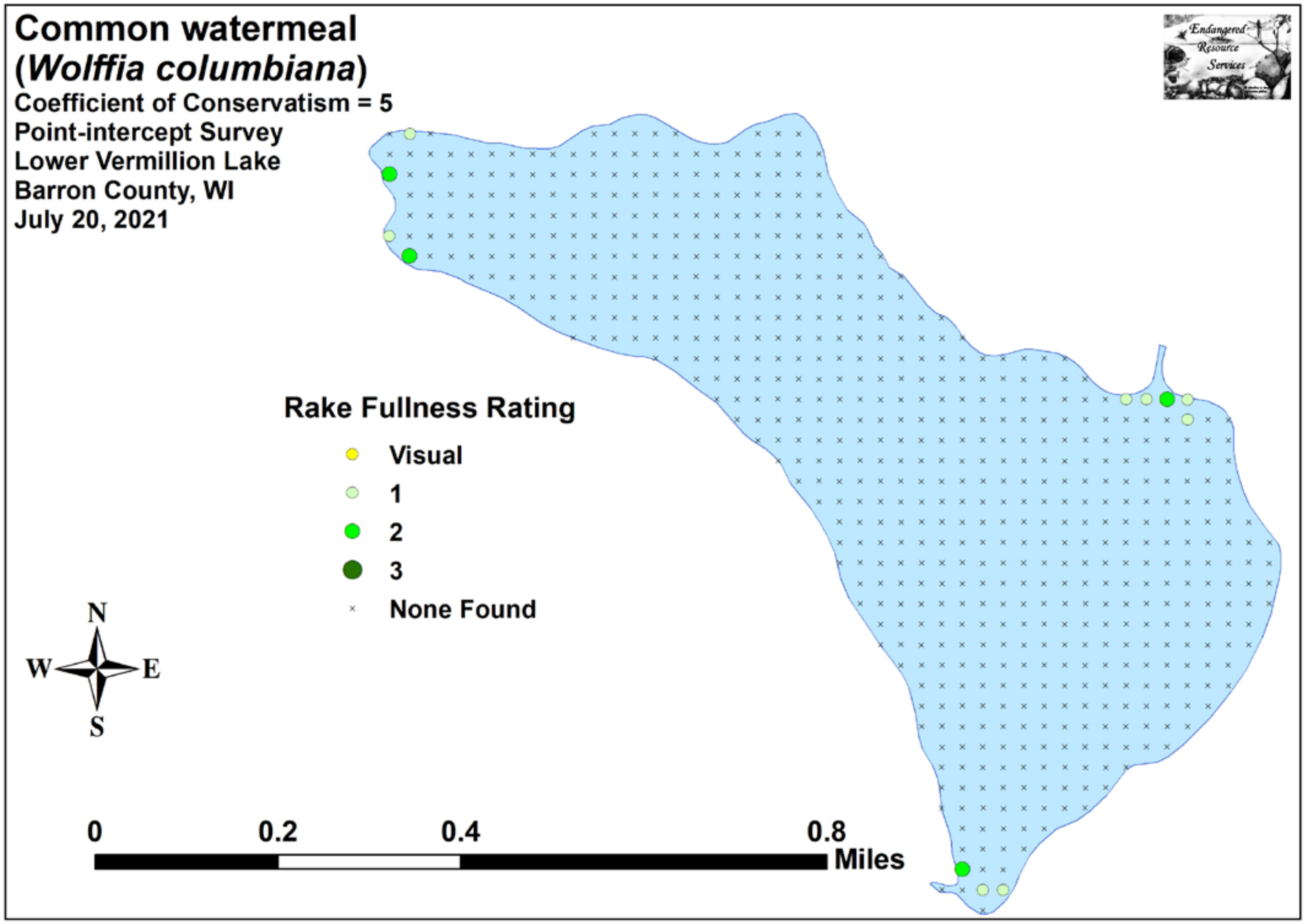
Common watermeal
(Wolffia columbiana)
Coefficient of Conservatism = 5
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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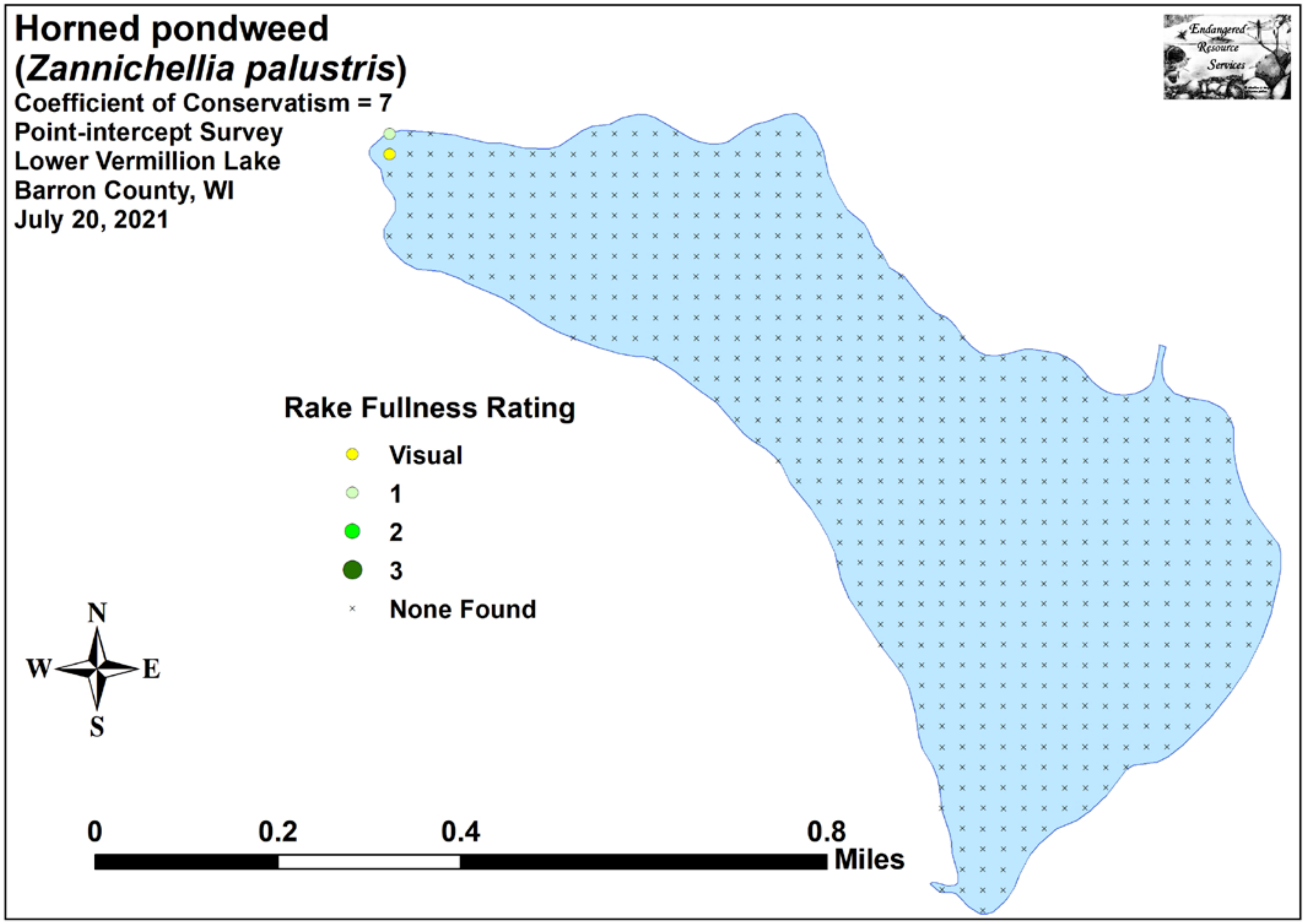
Horned pondweed
(Zannichellia palustris)
Coefficient of Conservatism = 7
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
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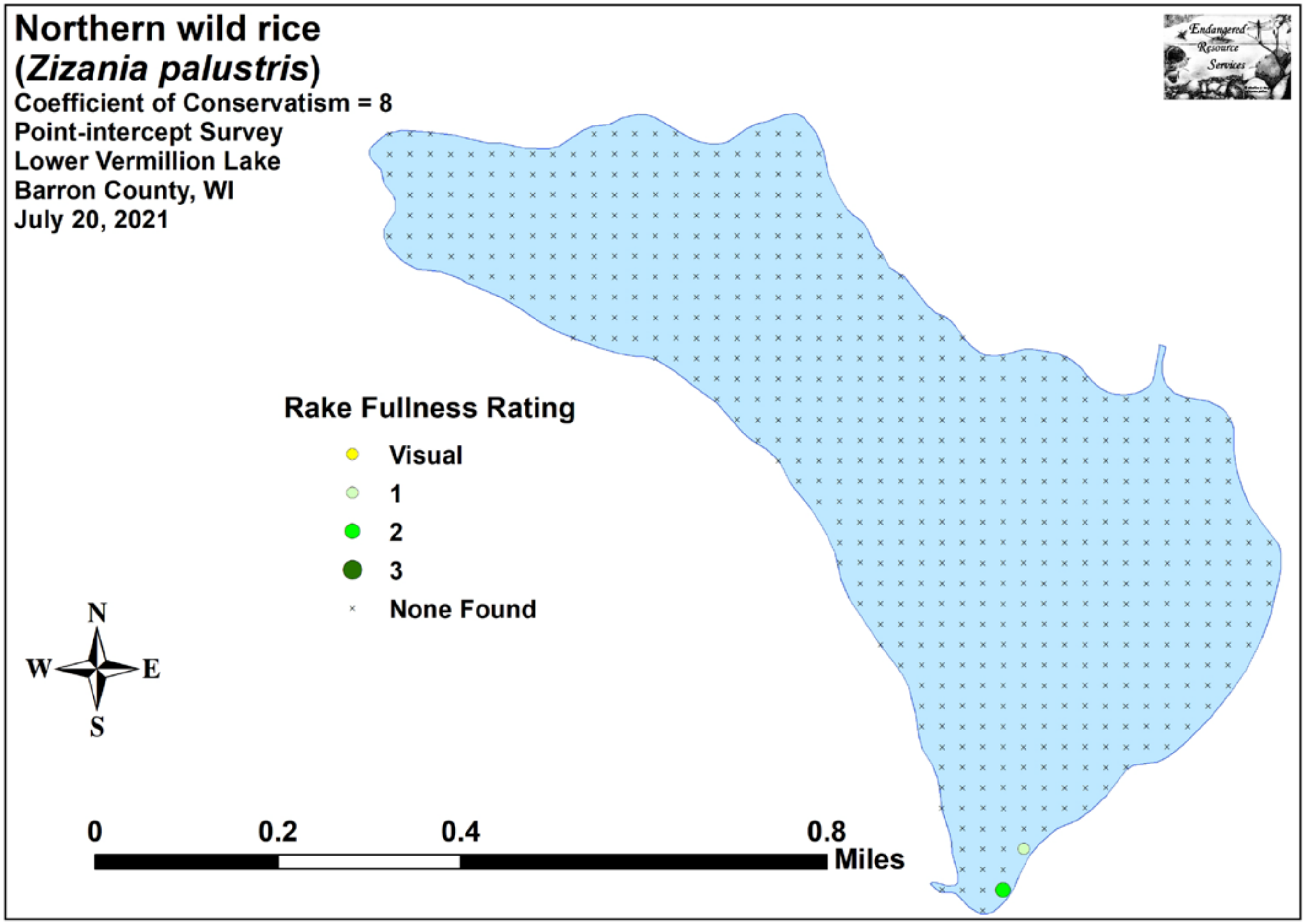
Northern wild rice
(Zizania palustris)
Coefficient of Conservatism = 8
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
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None Found
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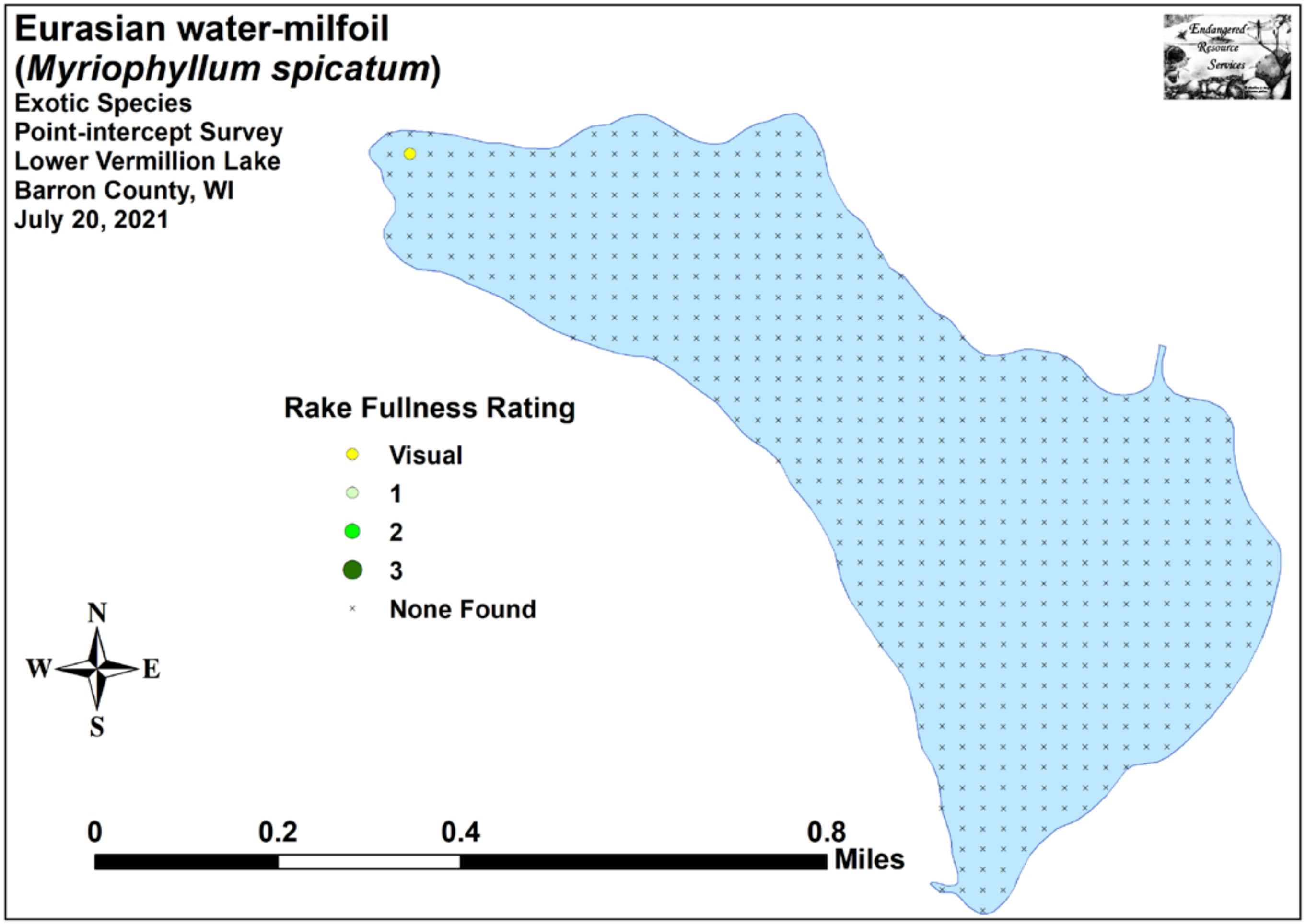
Miles

Appendix VIII: July 2021 Exotic Species Density and Distribution Maps


Eurasian water-milfoil
(Myriophyllum spicatum)
Exotic Species
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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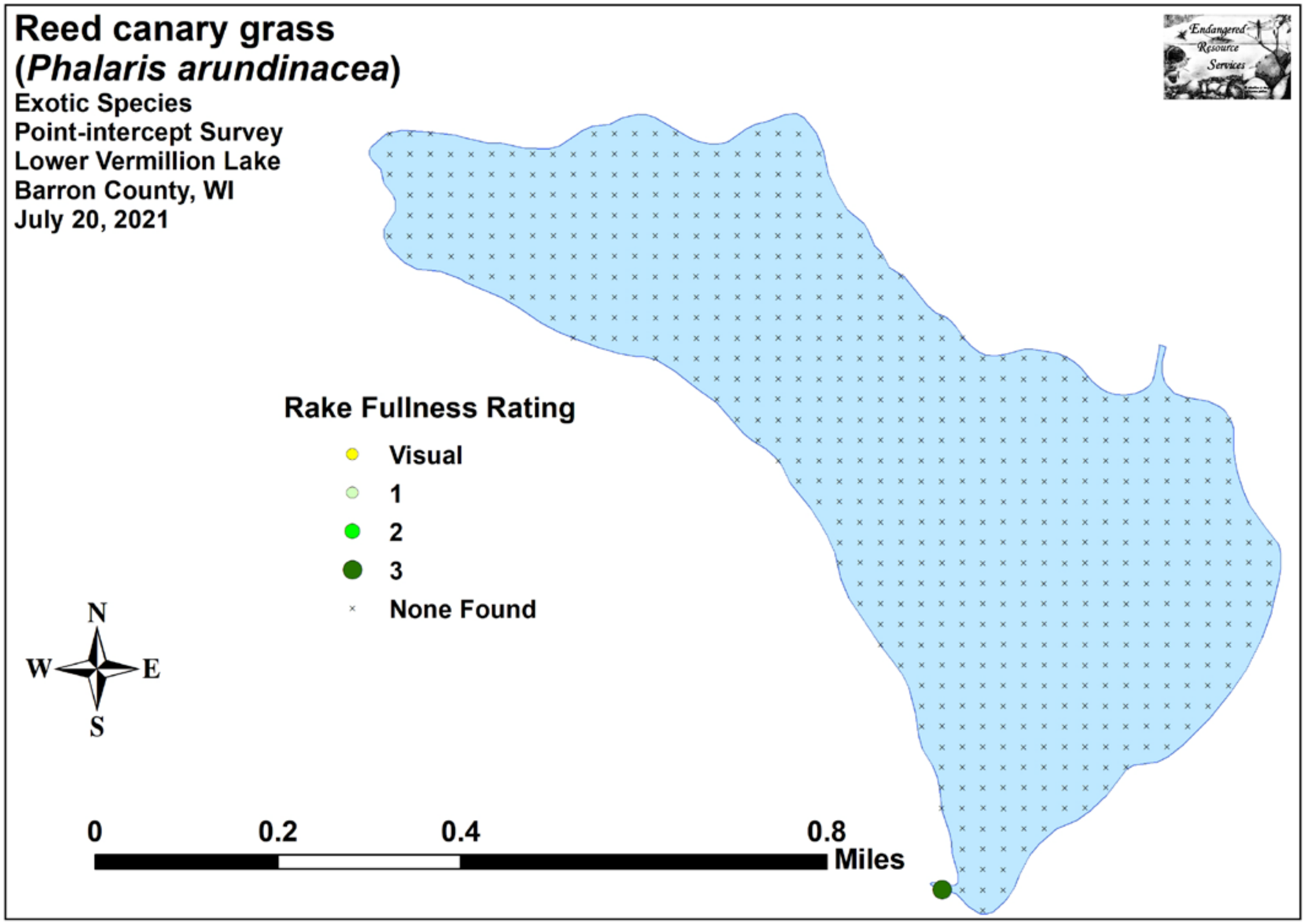
Reed canary grass
(Phalaris arundinacea)
Exotic Species
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Rake Fullness Rating
Visual
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None Found
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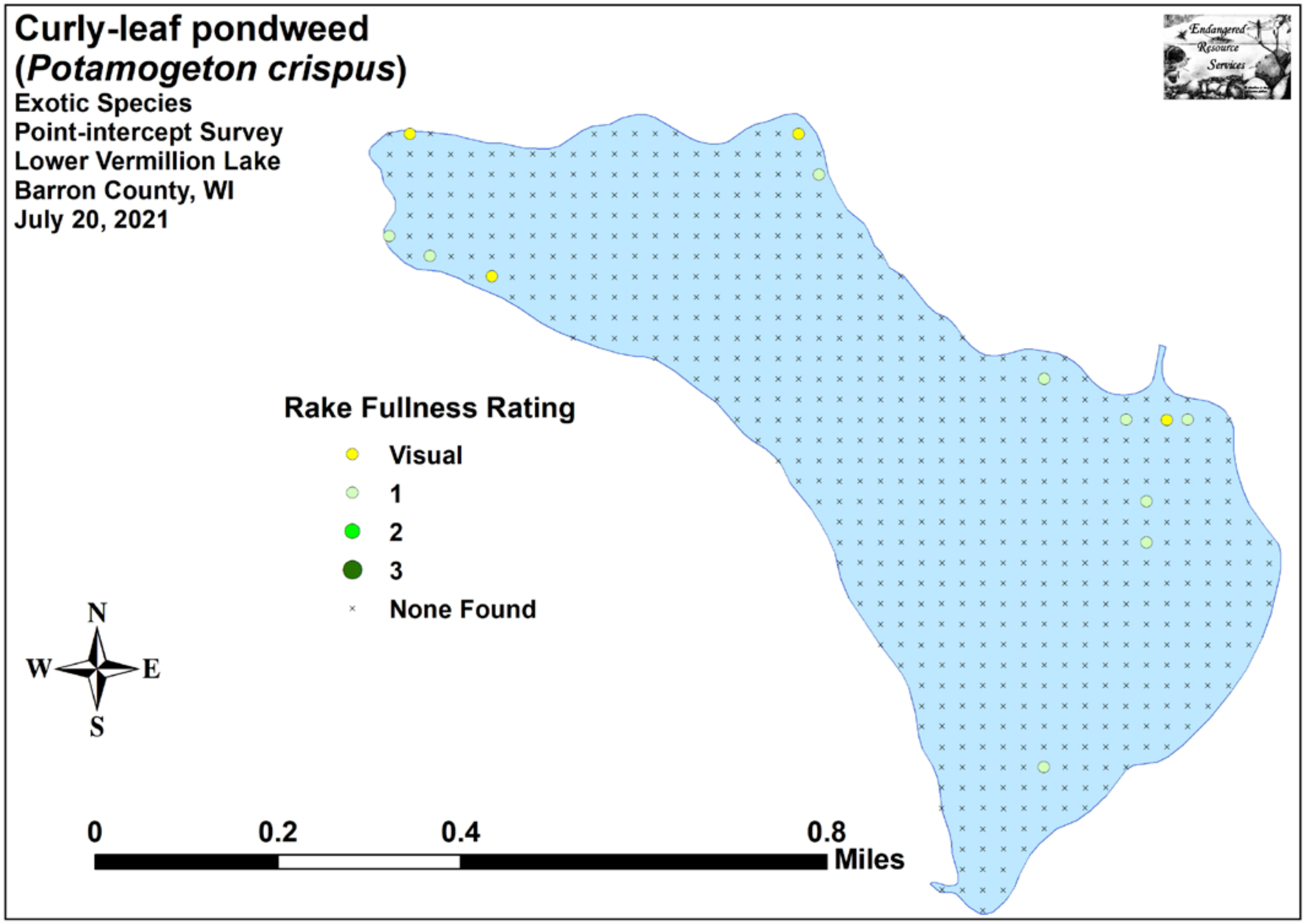
Miles



Curly-leaf pondweed
(Potamogeton crispus)
Exotic Species
Point-intercept Survey
Lower Vermillion Lake
Barron County, WI
July 20, 2021
Endangered Resource Services
Rake Fullness Rating
Visual
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None Found
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Miles

Appendix IX: Aquatic Exotic Invasive Plant Species Information

Eurasian Water-milfoil

DESCRIPTION: Eurasian Water-milfoil is a submersed aquatic plant native to Europe, Asia, and northern Africa. It is the only non-native milfoil in Wisconsin. Like the native milfoils, the Eurasian variety has slender stems whorled by submersed feathery leaves and tiny flowers produced above the water surface. The flowers are located in the axils of the floral bracts, and are either four-petaled or without petals. The leaves are threadlike, typically uniform in diameter, and aggregated into a submersed terminal spike. The stem thickens below the inflorescence and doubles its width further down, often curving to lie parallel with the water surface. The fruits are four-jointed nut-like bodies. Without flowers or fruits, Eurasian Water-milfoil is nearly impossible to distinguish from Northern Water-milfoil. Eurasian Water-milfoil has 9-21 pairs of leaflets per leaf, while Northern milfoil typically has 7-11 pairs of leaflets. Coontail is often mistaken for the milfoils, but does not have individual leaflets.

DISTRIBUTION AND HABITAT: Eurasian milfoil first arrived in Wisconsin in the 1960's. During the 1980's, it began to move from several counties in southern Wisconsin to lakes and waterways in the northern half of the state. As of 1993, Eurasian milfoil was common in 39 Wisconsin counties (54%) and at least 75 of its lakes, including shallow bays in Lakes Michigan and Superior and Mississippi River pools.

Eurasian Water-milfoil grows best in fertile, fine-textured, inorganic sediments. In less productive lakes, it is restricted to areas of nutrient-rich sediments. It has a history of becoming dominant in eutrophic, nutrient-rich lakes, although this pattern is not universal. It is an opportunistic species that prefers highly disturbed lake beds, lakes receiving nitrogen and phosphorous-laden runoff, and heavily used lakes. Optimal growth occurs in alkaline systems with a high concentration of dissolved inorganic carbon. High water temperatures promote multiple periods of flowering and fragmentation.

LIFE HISTORY AND EFFECTS OF INVASION: Unlike many other plants, Eurasian Water-milfoil does not rely on seed for reproduction. Its seeds germinate poorly under natural conditions. It reproduces vegetatively by fragmentation, allowing it to disperse over long distances. The plant produces fragments after fruiting once or twice during the summer. These shoots may then be carried downstream by water currents or inadvertently picked up by boaters. Milfoil is readily dispersed by boats, motors, trailers, bilges, live wells, or bait buckets, and can stay alive for weeks if kept moist.

Once established in an aquatic community, milfoil reproduces from shoot fragments and stolons (runners that creep along the lake bed). As an opportunistic species, Eurasian Water-milfoil is adapted for rapid growth early in spring. Stolons, lower stems, and roots persist over winter and store the carbohydrates that help milfoil claim the water column early in spring, photosynthesize, divide, and form a dense leaf canopy that shades out native aquatic plants. Its ability to spread rapidly by fragmentation and effectively block out sunlight needed for native plant growth often results in monotypic stands. Monotypic stands of Eurasian milfoil provide only a single habitat, and threaten the integrity of aquatic communities in a number of ways; for example, dense stands disrupt predator-prey relationships by fencing out larger fish, and reducing the number of nutrient-rich native plants available for waterfowl.

Dense stands of Eurasian Water-milfoil also inhibit recreational uses like swimming, boating, and fishing. Some stands have been dense enough to obstruct industrial and power generation water intakes. The visual impact that greets the lake user on milfoil-dominated lakes is the flat yellow-green of matted vegetation, often prompting the perception that the lake is "infested" or "dead". Cycling of nutrients from sediments to the water column by Eurasian Water-milfoil may lead to deteriorating water quality and algae blooms of infested lakes. (Taken in its entirety from WDNR, 2010 http://www.dnr.state.wi.us/invasives/fact/milfoil.htm)

Curly-leaf pondweed

DESCRIPTION: Curly-leaf pondweed is an invasive aquatic perennial that is native to Eurasia, Africa, and Australia. It was accidentally introduced to United States waters in the mid-1880s by hobbyists who used it as an aquarium plant. The leaves are reddish-green, oblong, and about 3 inches long, with distinct wavy edges that are finely toothed. The stem of the plant is flat, reddish-brown and grows from 1 to 3 feet long. The plant usually drops to the lake bottom by early August

DISTRIBUTION AND HABITAT: Curly-leaf pondweed is commonly found in alkaline and high nutrient waters, preferring soft substrate and shallow water depths. It tolerates low light and low water temperatures. It has been reported in all states but Maine

LIFE HISTORY AND EFFECTS OF INVASION: Curly-leaf pondweed spreads through burr-like winter buds (turions), which are moved among waterways. These plants can also reproduce by seed, but this plays a relatively small role compared to the vegetative reproduction through turions. New plants form under the ice in winter, making curly-leaf pondweed one of the first nuisance aquatic plants to emerge in the spring.

It becomes invasive in some areas because of its tolerance for low light and low water temperatures. These tolerances allow it to get a head start on and out compete native plants in the spring. In mid-summer, when most aquatic plants are growing, curly-leaf pondweed plants are dying off. Plant die-offs may result in a critical loss of dissolved oxygen. Furthermore, the decaying plants can increase nutrients which contribute to algal blooms, as well as create unpleasant stinking messes on beaches. Curly-leaf pondweed forms surface mats that interfere with aquatic recreation. (Taken in its entirety from WDNR, 2010 http://www.dnr.state.wi.us/invasives/fact/curlyleaf_pondweed.htm)

Reed canary grass

DESCRIPTION: Reed canary grass is a large, coarse grass that reaches 2 to 9 feet in height. It has an erect, hairless stem with gradually tapering leaf blades 3 1/2 to 10 inches long and 1/4 to 3/4 inch in width. Blades are flat and have a rough texture on both surfaces. The lead ligule is membranous and long. The compact panicles are erect or slightly spreading (depending on the plant's reproductive stage), and range from 3 to 16 inches long with branches 2 to 12 inches in length. Single flowers occur in dense clusters in May to mid-June. They are green to purple at first and change to beige over time. This grass is one of the first to sprout in spring, and forms a thick rhizome system that dominates the subsurface soil. Seeds are shiny brown in color.

Both Eurasian and native ecotypes of reed canary grass are thought to exist in the U.S. The Eurasian variety is considered more aggressive, but no reliable method exists to tell the ecotypes apart. It is believed that the vast majority of our reed canary grass is derived from the Eurasian ecotype. Agricultural cultivars of the grass are widely planted.

Reed canary grass also resembles non-native orchard grass (*Dactylis glomerata*), but can be distinguished by its wider blades, narrower, more pointed inflorescence, and the lack of hairs on glumes and lemmas (the spikelet scales). Additionally, bluejoint grass (*Calamagrostis canadensis*) may be mistaken for reed canary in areas where orchard grass is rare, especially in the spring. The highly transparent ligule on reed canary grass is helpful in distinguishing it from the others. Ensure positive identification before attempting control.

DISTRIBUTION AND HABITAT: Reed canary grass is a cool-season, sod-forming, perennial wetland grass native to temperate regions of Europe, Asia, and North America. The Eurasian ecotype has been selected for its vigor and has been planted throughout the U.S. since the 1800's for forage and erosion control. It has become naturalized in much of the northern half of the U.S., and is still being planted on steep slopes and banks of ponds and created wetlands.

Reed canary grass can grow on dry soils in upland habitats and in the partial shade of oak woodlands, but does best on fertile, moist organic soils in full sun. This species can invade most types of wetlands, including marshes, wet prairies, sedge meadows, fens, stream banks, and seasonally wet areas; it also grows in disturbed areas such as bergs and spoil piles.

LIFE HISTORY AND EFFECTS OF INVASION: Reed canary grass reproduces by seed or creeping rhizomes. It spreads aggressively. The plant produces leaves and flower stalks for 5 to 7 weeks after germination in early spring, then spreads laterally. Growth peaks in mid-June and declines in mid-August. A second growth spurt occurs in the fall. The shoots collapse in mid to late summer, forming a dense, impenetrable mat of stems and leaves. The seeds ripen in late June and shatter when ripe. Seeds may be dispersed from one wetland to another by waterways, animals, humans, or machines.

This species prefers disturbed areas, but can easily move into native wetlands. Reed canary grass can invade a disturbed wetland in less than twelve years. Invasion is associated with disturbances including ditching of wetlands, stream channelization, deforestation of swamp forests, sedimentation, and intentional planting. The difficulty of selective control makes reed canary grass invasion of particular concern. Over time, it forms large, monotypic stands that harbor few other plant species and are subsequently of little use to wildlife. Once established, reed canary grass dominates an area by building up a tremendous seed bank that can eventually erupt, germinate, and recolonize treated sites. (Taken in its entirety from WDNR, 2010 http://www.dnr.state.wi.us/invasives/fact/reed_canary.htm)

Purple loosestrife
(Photo Courtesy Brian M. Collins)

DESCRIPTION: Purple loosestrife is a perennial herb 3-7 feet tall with a dense bushy growth of 1-50 stems. The stems, which range from green to purple, die back each year. Showy flowers vary from purple to magenta, possess 5-6 petals aggregated into numerous long spikes, and bloom from August to September. Leaves are opposite, nearly linear, and attached to four-sided stems without stalks. It has a large, woody taproot with fibrous rhizomes that form a dense mat.

This species may be confused with the native wing-angled loosestrife (*Lythrum alatum*) found in moist prairies or wet meadows. The latter has a winged, square stem and solitary paired flowers in the leaf axils. It is generally a smaller plant than the Eurasian loosestrife.

By law, purple loosestrife is a nuisance species in Wisconsin. It is illegal to sell, distribute, or cultivate the plants or seeds, including any of its cultivars.

DISTRIBUTION AND HABITAT: Purple loosestrife is a wetland herb that was introduced as a garden perennial from Europe during the 1800's. It is still promoted by some horticulturists for its beauty as a landscape plant, and by beekeepers for its nectar-producing capability. Currently, about 24 states have laws prohibiting its importation or distribution because of its aggressively invasive characteristics. It has since extended its range to include most temperate parts of the United States and Canada. The plant's reproductive success across North America can be attributed to its wide tolerance of physical and chemical conditions characteristic of disturbed habitats, and its ability to reproduce prolifically by both seed dispersal and vegetative propagation. The absence of natural predators, like European species of herbivorous beetles that feed on the plant's roots and leaves, also contributes to its proliferation in North America

LIFE HISTORY AND EFFECTS OF INVASION: Purple loosestrife can germinate successfully on substrates with a wide range of pH. Optimum substrates for growth are moist soils of neutral to slightly acidic pH, but it can exist in a wide range of soil types. Most seedling establishment occurs in late spring and early summer when temperatures are high.

Purple loosestrife spreads mainly by seed, but it can also spread vegetatively from root or stem segments. A single stalk can produce from 100,000 to 300,000 seeds per year. Seed survival is up to 60-70%, resulting in an extensive seed bank. Mature plants with up to 50 shoots grow over 2 meters high and produce more than two million seeds a year. Germination is restricted to open, wet soils and requires high temperatures, but seeds remain viable in the soil for many years. Even seeds submerged in water can live for approximately 20 months. Most of the seeds fall near the parent plant, but water, animals, boats, and humans can transport the seeds long distances. Vegetative spread through local perturbation is also characteristic of loosestrife; clipped, trampled, or buried stems of established plants may produce shoots and roots. Plants may be quite large and several years old before they begin flowering. It is often very difficult to locate non-flowering plants, so monitoring for new invasions should be done at the beginning of the flowering period in mid-summer.

Any sunny or partly shaded wetland is susceptible to purple loosestrife invasion. Vegetative disturbances such as water drawdown or exposed soil accelerate the process by providing ideal conditions for seed germination. Invasion usually begins with a few pioneering plants that build up a large seed bank in the soil for several years. When the right disturbance occurs, loosestrife can spread rapidly, eventually taking over the entire wetland. The plant can also make morphological adjustments to accommodate changes in the immediate environment; for example, a decrease in light level will trigger a change in leaf morphology. The plant's ability to adjust to a wide range of environmental conditions gives it a competitive advantage; coupled with its reproductive strategy, purple loosestrife tends to create monotypic stands that reduce biotic diversity.

Purple loosestrife displaces native wetland vegetation and degrades wildlife habitat. As native vegetation is displaced, rare plants are often the first species to disappear. Eventually, purple loosestrife can overrun wetlands thousands of acres in size, and almost entirely eliminate the open water habitat. The plant can also be detrimental to recreation by choking waterways. (Taken in its entirety from WDNR, 2010 http://www.dnr.state.wi.us/invasives/fact/loosestrife.htm)

Appendix X: Glossary of Biological Terms
(Adapted from UWEX 2010)

Aquatic:
organisms that live in or frequent water.

Cultural Eutrophication:
accelerated eutrophication that occurs as a result of human activities in the watershed that increase nutrient loads in runoff water that drains into lakes.

Dissolved Oxygen (DO):
the amount of free oxygen absorbed by the water and available to aquatic organisms for respiration; amount of oxygen dissolved in a certain amount of water at a particular temperature and pressure, often expressed as a concentration in parts of oxygen per million parts of water.

Diversity:
number and evenness of species in a particular community or habitat.

Drainage lakes:
Lakes fed primarily by streams and with outlets into streams or rivers. They are more subject to surface runoff problems but generally have shorter residence times than seepage lakes. Watershed protection is usually needed to manage lake water quality.

Ecosystem:
a system formed by the interaction of a community of organisms with each other and with the chemical and physical factors making up their environment.

Eutrophication:
the process by which lakes and streams are enriched by nutrients, and the resulting increase in plant and algae growth. This process includes physical, chemical, and biological changes that take place after a lake receives inputs for plant nutrients--mostly nitrates and phosphates--from natural erosion and runoff from the surrounding land basin. The extent to which this process has occurred is reflected in a lake's trophic classification: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile).

Exotic:
a non-native species of plant or animal that has been introduced.

Habitat:
the place where an organism lives that provides an organism's needs for water, food, and shelter. It includes all living and non-living components with which the organism interacts.

Limnology:
the study of inland lakes and waters.

Littoral:

the near shore shallow water zone of a lake, where aquatic plants grow.

Macrophytes:

Refers to higher (multi-celled) plants growing in or near water. Macrophytes are beneficial to lakes because they produce oxygen and provide substrate for fish habitat and aquatic insects. Overabundance of such plants, especially problem species, is related to shallow water depth and high nutrient levels.

Nutrients:

elements or substances such as nitrogen and phosphorus that are necessary for plant growth. Large amounts of these substances can become a nuisance by promoting excessive aquatic plant growth.

Organic Matter:

elements or material containing carbon, a basic component of all living matter.

Photosynthesis:

the process by which green plants convert carbon dioxide (CO2) dissolved in water to sugar and oxygen using sunlight for energy. Photosynthesis is essential in producing a lake's food base, and is an important source of oxygen for many lakes.

Phytoplankton:

microscopic plants found in the water. Algae or one-celled (phytoplankton) or multicellular plants either suspended in water (Plankton) or attached to rocks and other substrates (periphyton). Their abundance, as measured by the amount of chlorophyll a (green pigment) in an open water sample, is commonly used to classify the trophic status of a lake. Numerous species occur. Algae are an essential part of the lake ecosystem and provides the food base for most lake organisms, including fish. Phytoplankton populations vary widely from day to day, as life cycles are short.

Plankton:

small plant organisms (phytoplankton and nanoplankton) and animal organisms (zooplankton) that float or swim weakly though the water.

ppm:

parts per million; units per equivalent million units; equal to milligrams per liter (mg/l)

Richness:
number of species in a particular community or habitat.

Rooted Aquatic Plants:
(macrophytes) Refers to higher (multi-celled) plants growing in or near water. Macrophytes are beneficial to lakes because they produce oxygen and provide substrate for fish habitat and aquatic insects. Overabundance of such plants, especially problem species, is related to shallow water depth and high nutrient levels.

Runoff:
water that flows over the surface of the land because the ground surface is impermeable or unable to absorb the water.

Secchi Disc:
An 8-inch diameter plate with alternating quadrants painted black and white that is used to measure water clarity (light penetration). The disc is lowered into water until it disappears from view. It is then raised until just visible. An average of the two depths, taken from the shaded side of the boat, is recorded as the Secchi disc reading. For best results, the readings should be taken on sunny, calm days.

Seepage lakes:
Lakes without a significant inlet or outlet, fed by rainfall and groundwater. Seepage lakes lose water through evaporation and groundwater moving on a down gradient. Lakes with little groundwater inflow tend to be naturally acidic and most susceptible to the effects of acid rain. Seepage lakes often have long, residence times. and lake levels fluctuate with local groundwater levels. Water quality is affected by groundwater quality and the use of land on the shoreline.

Turbidity:
degree to which light is blocked because water is muddy or cloudy.

Watershed:
the land area draining into a specific stream, river, lake or other body of water. These areas are divided by ridges of high land.

Zooplankton:
Microscopic or barely visible animals that eat algae. These suspended plankton are an important component of the lake food chain and ecosystem. For many fish, they are the primary source of food.

Appendix XI: 2021 Raw Data Spreadsheets

Lower Vermillion BarronCoWBIC2098200 CLPEWMPI Survey Final Data 5 29 2021MBergERSLLC.xlsx

Lower Vermillion BarronCoWBIC2098200 PI Survey Final Data 7 20 2021MBergERSLLC.xlsx